Advanced intelligent Clear-IQ Engine (AiCE)

— Deep Learning Reconstruction

powered by Altivity

In a time when resources are limited, and healthcare systems are overwhelmed by constant pressure, we are doing everything we can to help you thrive. Our goal, driven by our **"Made for Life"** philosophy, has always been to help you deliver informed healthcare with efficient workflows, so your patients can receive the fast, tailored treatment they need. We are taking this to a new level with the power of Artificial Intelligence (AI).

One such solution leveraging the power of AI is our Deep Learning Reconstruction technology, Advanced intelligent Clear-IQ Engine (AiCE). AiCE combines our expertise in image reconstruction technologies with world-class medical science to boost image quality. Initially developed for CT, AiCE is now also available across our MR and PET-CT systems to improve image quality across the care cycle.

At the core of diagnostic imaging is high quality images that enable a confident diagnosis, even in challenging patients. We believe therefore that AiCE with its excellent noise reduction capabilities is the gold standard for image quality. Additionally it delivers excellent low contrast detectability, radiation dose reduction, and fast image reconstruction. Beyond the breakthroughs in image quality that enhance care in routine practice today, it has the potential to benefit the future downstream applications of AI, since it all starts with an image. As such, we are continuing our efforts to expand AiCE across our portfolio, so that more clinicians can enjoy the benefits of AiCE in their daily practice wherever and whenever they need it.

We invite you to see the difference for yourself. Thank you for taking the time to learn more about this innovation.

Wataru Taguchi
Senior Vice President
Canon Medical Systems Corporation

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Welcome to the age of AI-assisted CT

Advanced intelligent Clear-IQ Engine (AiCE) – Deep Learning Reconstruction (DLR) for sharp, clear and distinct images

AiCE is an innovative approach to CT reconstruction that uses Deep Learning technology to match the spatial resolution and low-noise properties of advanced model-based iterative reconstructions.

Trained using vast amounts of high-quality image data, reconstructed with an advanced model-based iterative reconstruction (MBIR) algorithm, AiCE distinguishes true signal from noise to deliver exceptional images at low radiation dose.

Furthermore, AiCE can be seamlessly integrated into your routine exam protocols to reconstruct images at a speed fast enough to keep pace in a busy clinical setting while delivering up to 82.4%[1] reduced dose levels compared to conventional reconstruction technology (Filtered Backprojection).

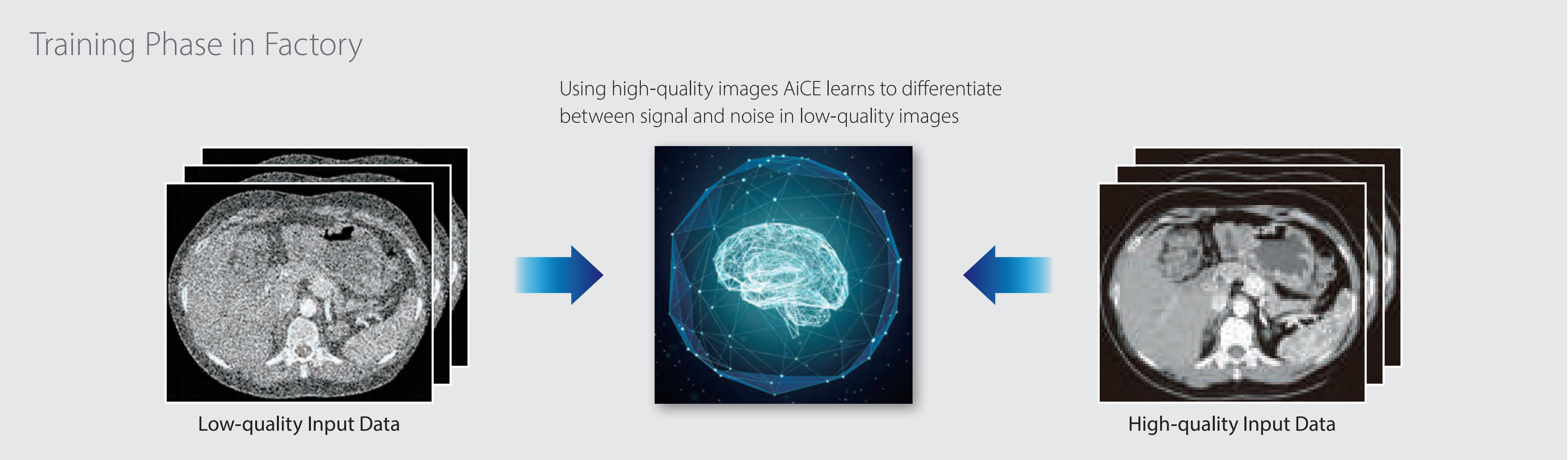
AiCE has potential to aid in fast and confident clinical results by providing:

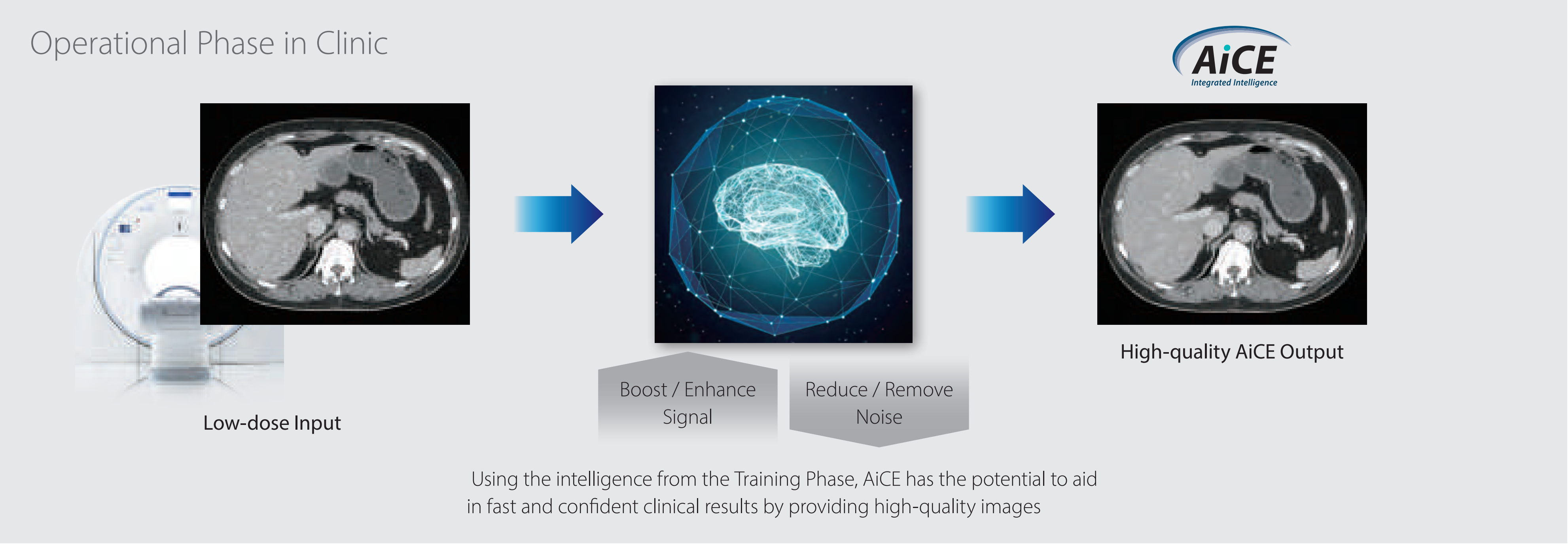
- Low noise
- Natural image Texture[2]
- Sharp high-contrast resolution
- Clear low-contrast detectability

Hybrid IR

AiCE

1 Validated on Aquilion ONE / GENESIS Edition
2 Natural defined as similar to FBP compared to MBIR. This does not apply to Aquilion Precision



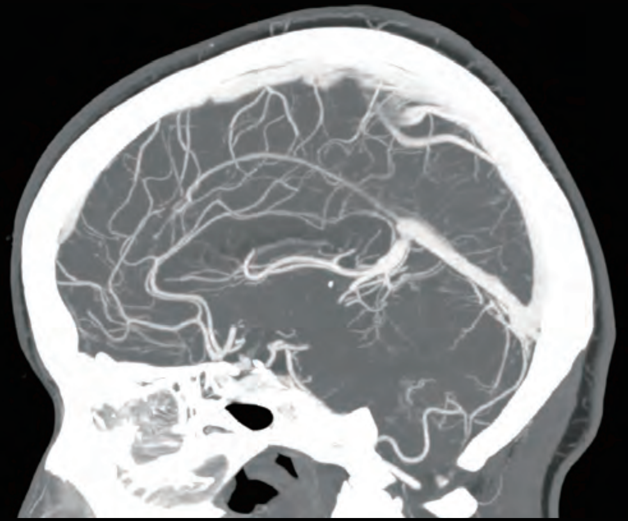


Reduced noise, sharper images[3]

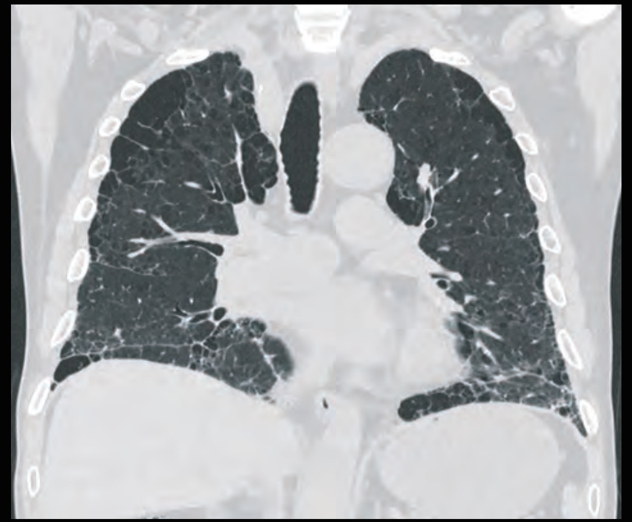
AiCE consists of a set of neural networks each individually trained for a specific anatomy to deliver sharp, clear and distinct images across body regions.

Brain

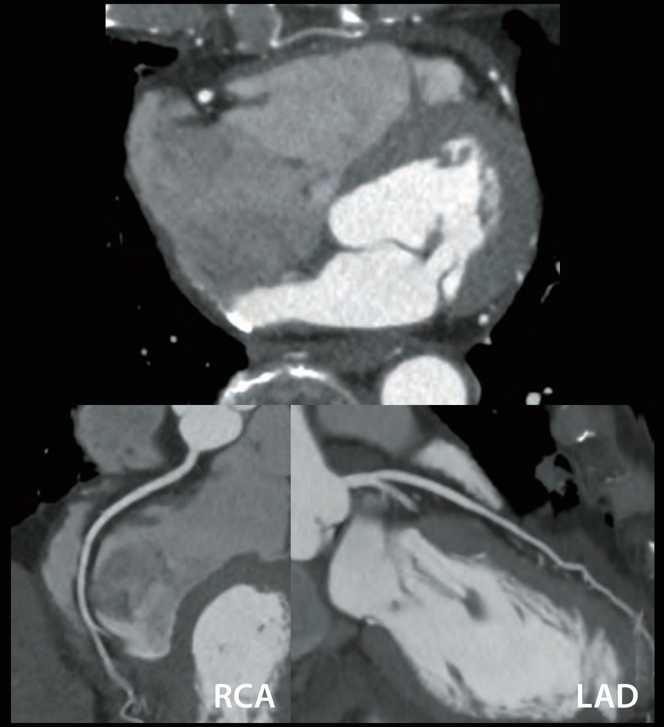
CTA



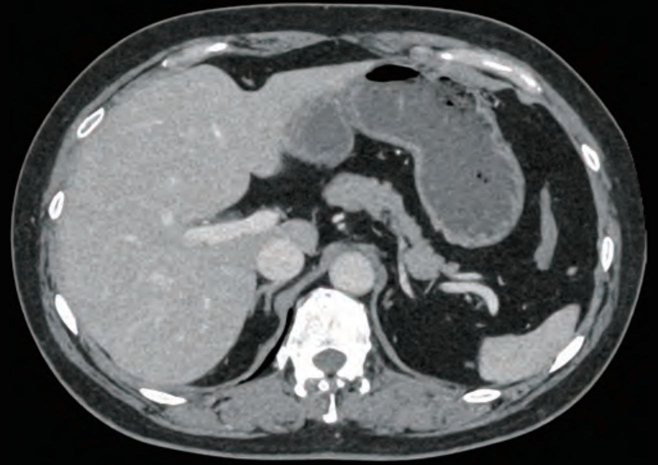
Lung



Cardiac



Body

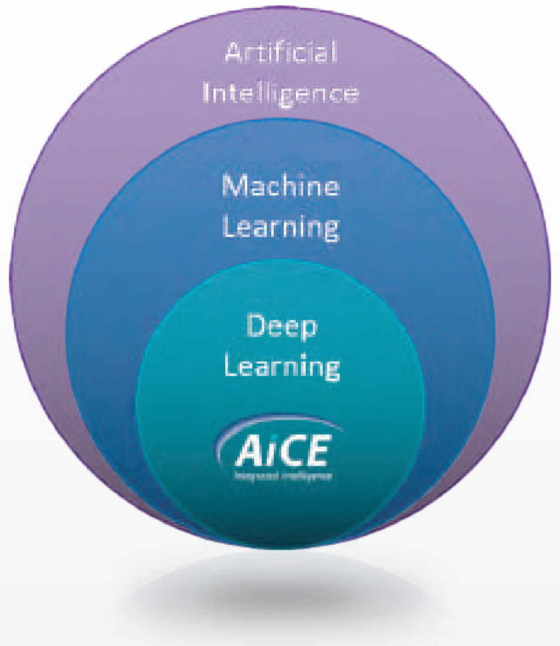


Bone

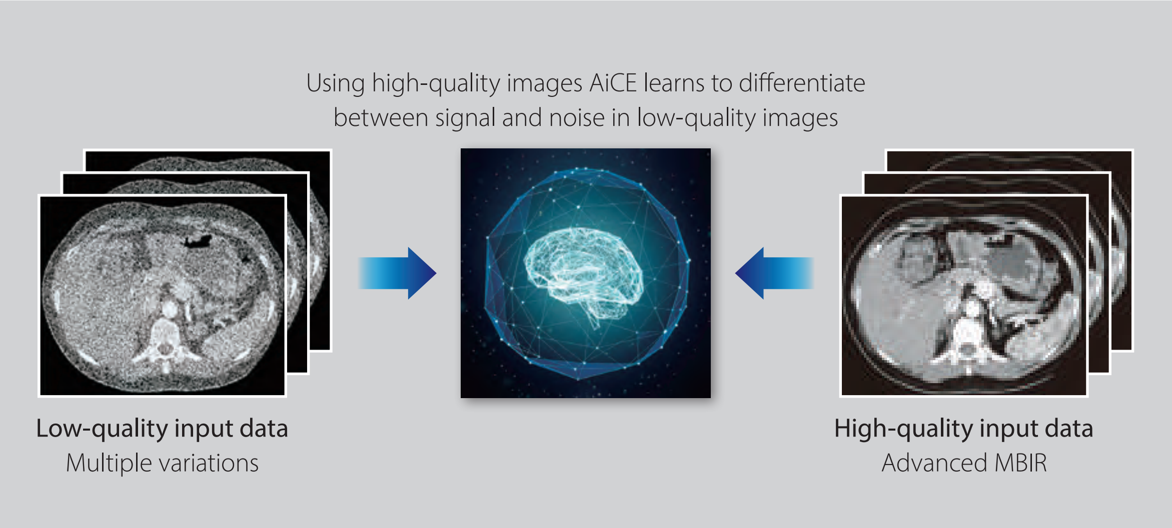
3 Compared to Hybrid IR

Unleashing the power of Deep Learning

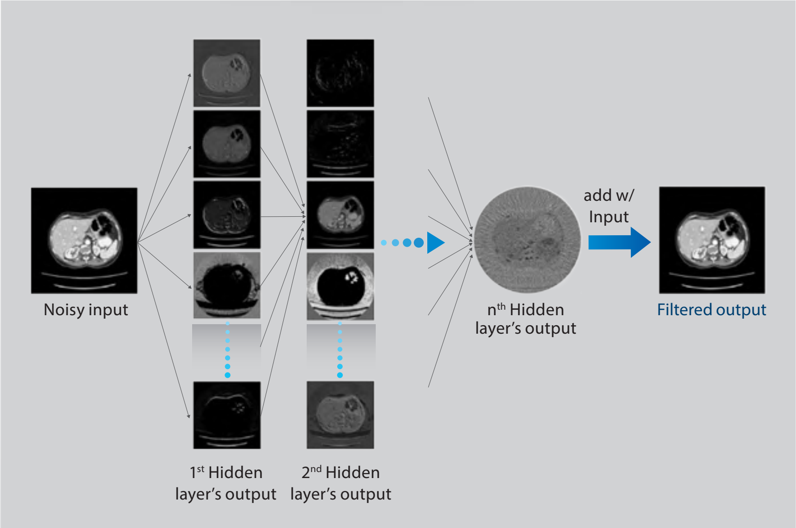
Deep Learning, one of the most sophisticated forms of AI, uses multiple layers of learning to extract progressively more detailed features from a raw input making it an ideal tool for performing tasks such as image recognition, segmentation and classification.



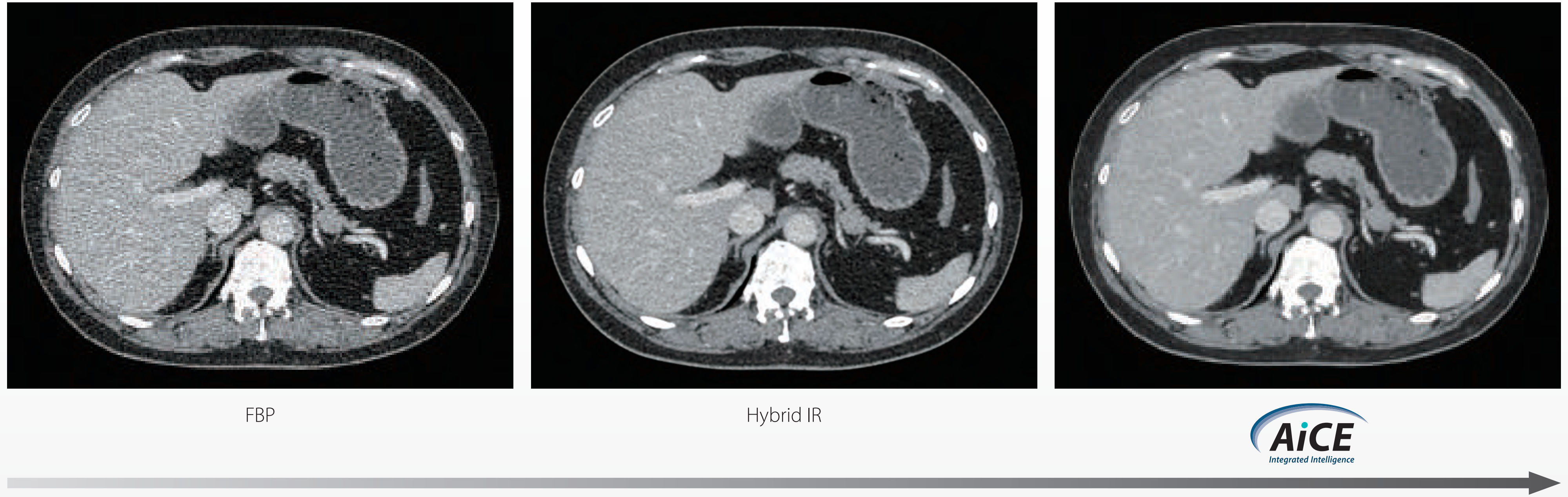
AiCE features a Deep Learning neural network that learns to differentiate signal from noise. Employing a network architecture optimized by AI scientists, AiCE learns multiple layers of feature information from a wide range of high-quality CT exams. The network architecture has very high-quality MBIR images set as target images for learning. Starting with multiple variations of low quality, noisy input data, the network compares these with the high-quality target images and through multiple layers of network learning learns to differentiate signal from noise.



Training with high quality MBIR images as target



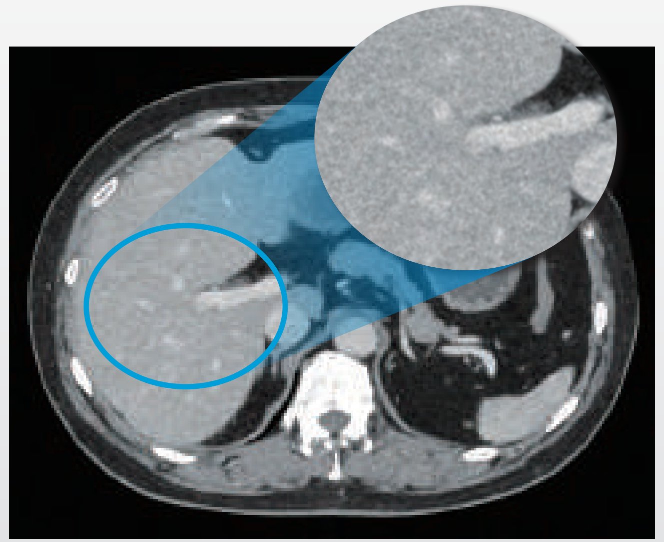
Multiple layers of feature extraction



MBIR's high spatial resolution and low noise represents anatomy more precisely than conventional reconstruction algorithms like Filtered Back Projection (FBP).

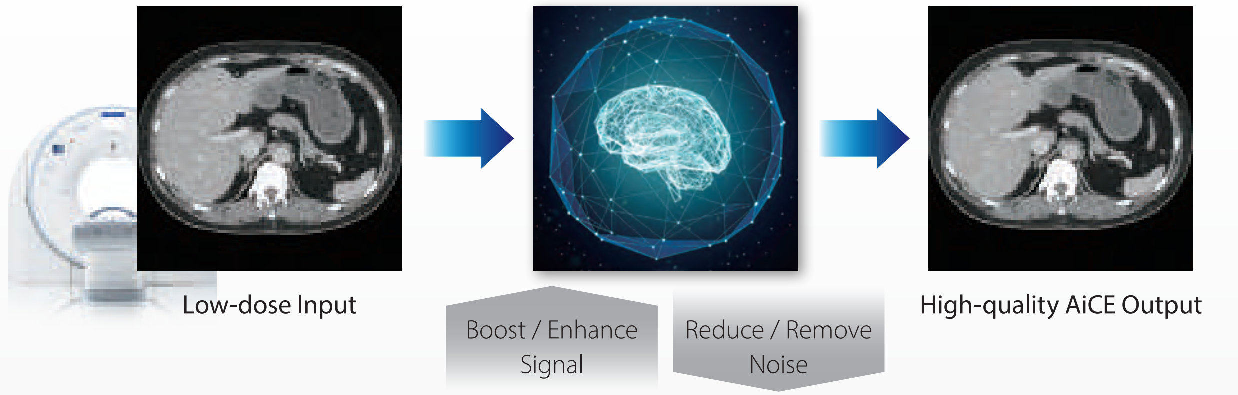
During training, AiCE learns to represent anatomy as precisely as the target MBIR images. The Deep Learning method identifies, preserves, and enhances signal while reducing noise. AiCE has its own noise texture, distinct and more natural in appearance than MBIR.

Thus, AiCE images have excellent signal properties and visually appealing texture, resulting in high-quality images to help increase your diagnostic confidence.



AiCE's distinct noise texture

In the final phase of training, AiCE Deep Learning network is streamlined for each scanner model to generate images at speeds fast enough to keep pace in a busy clinical setting.



Using the intelligence from the Training Phase, AiCE has the potential to aid in fast and confident clinical results by providing high-quality images

"AiCE image quality is superior to all other reconstruction technologies I have seen so far.

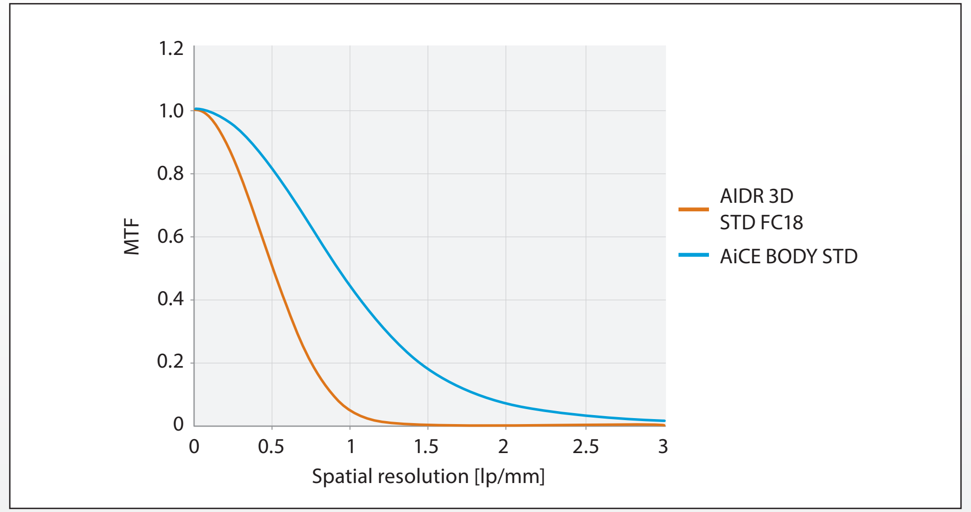
The noise is greatly reduced and the images have a natural texture appearance.

AiCE reconstruction is quick which allows use in every protocol without disturbing the workflow, even with double recons like we do for chest and chest-abdomen-pelvis examinations."

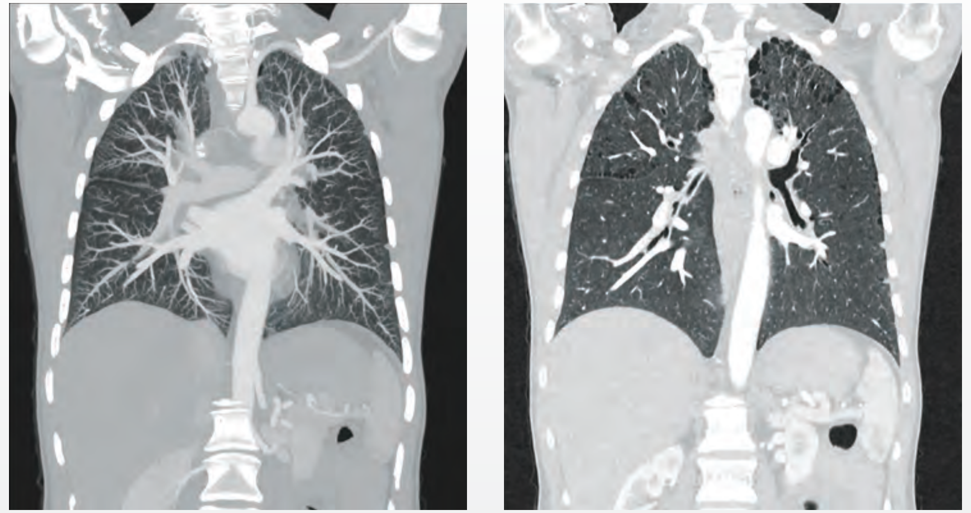
Professor Mathias Prokop MD, PhD
Chairman of the Department of Radiology & Nuclear Medicine
Radboud University Medical Center, Nijmegen, the Netherlands

Increased image quality at reduced patient doses[4]

Supervised training using high-quality, high-dose target training images reconstructed with advanced MBIR helps AiCE learn to preserve edge and maintain image detail, which is particularly important for lung and cardiac scanning.



For cardiac, the MTF[5] is greatly increased relative to the hybrid iterative reconstruction (AIDR 3D). Additionally, there is a 5% decrease in noise magnitude.



Routine chest with CE, **0.6 mSv**
For lung imaging, AiCE preserves high contrast spatial resolution in a manner similar to Adaptive Iterative Dose Reduction 3D (AIDR 3D) for lung, but with half the noise magnitude.

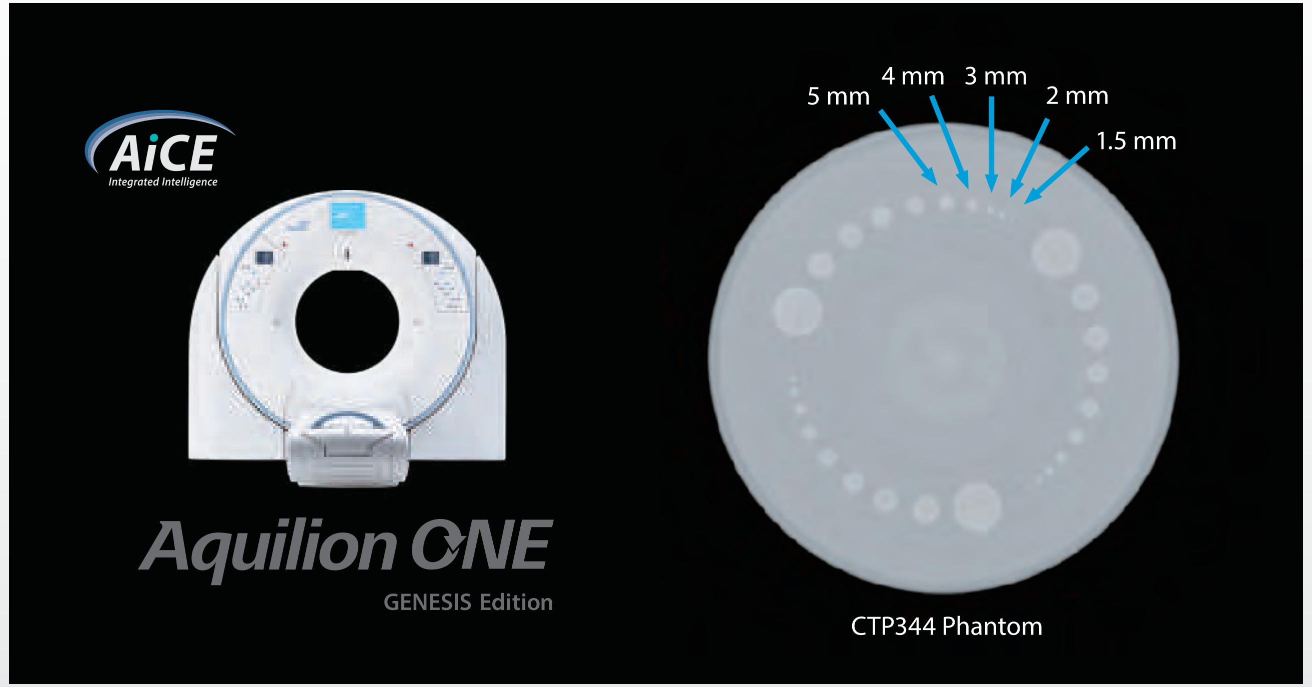
AiCE reduces radiation dose by up to 82.4%[6] compared to FBP. Additionally, AiCE is fully integrated into SUREExposure mA modulation system. The system automatically adjusts each individual patient's mA profile taking advantage of the excellent dose reduction abilities of AiCE reconstruction.

4 This does not apply to Aquilion Precision
5 Modulation Transfer Function (MTF) is measured on Aquilion ONE / GENESIS Edition
6 Validated on Aquilion ONE / GENESIS Edition

A new benchmark in Low Contrast Detectability (LCD)

AiCE dramatically decreases the magnitude of noise in an image, improving low contrast detectability (LCD). The improvement in LCD was so significant that it could not be sufficiently demonstrated using a standard Catphan®.

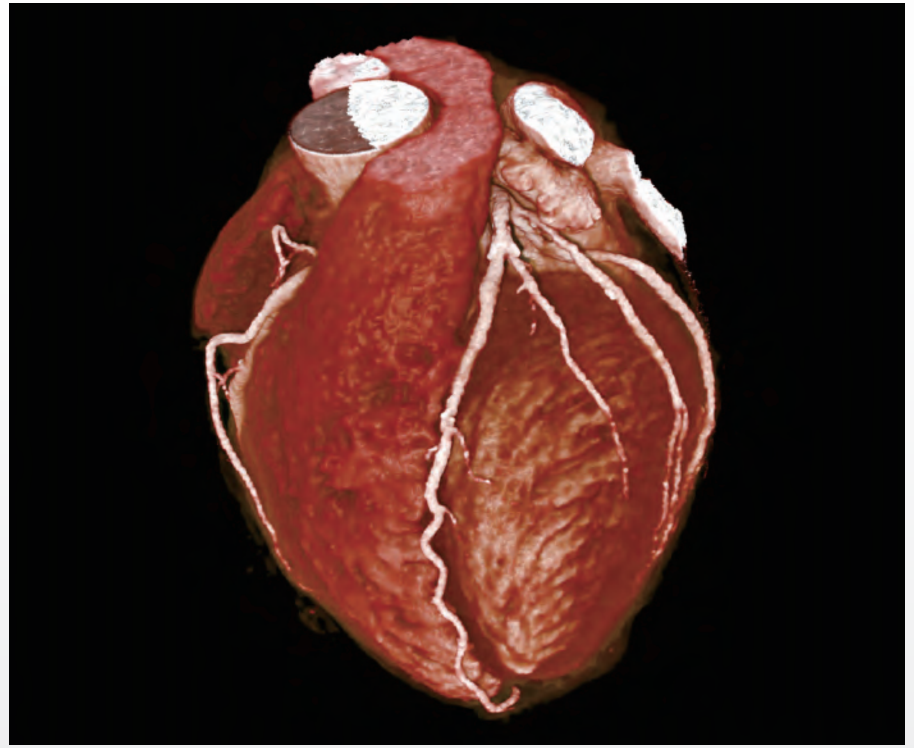
A custom Catphan® that included a new, more challenging test object of 1.5 mm diameter and 3 HU contrast had to be created to demonstrate an industry-first specification.

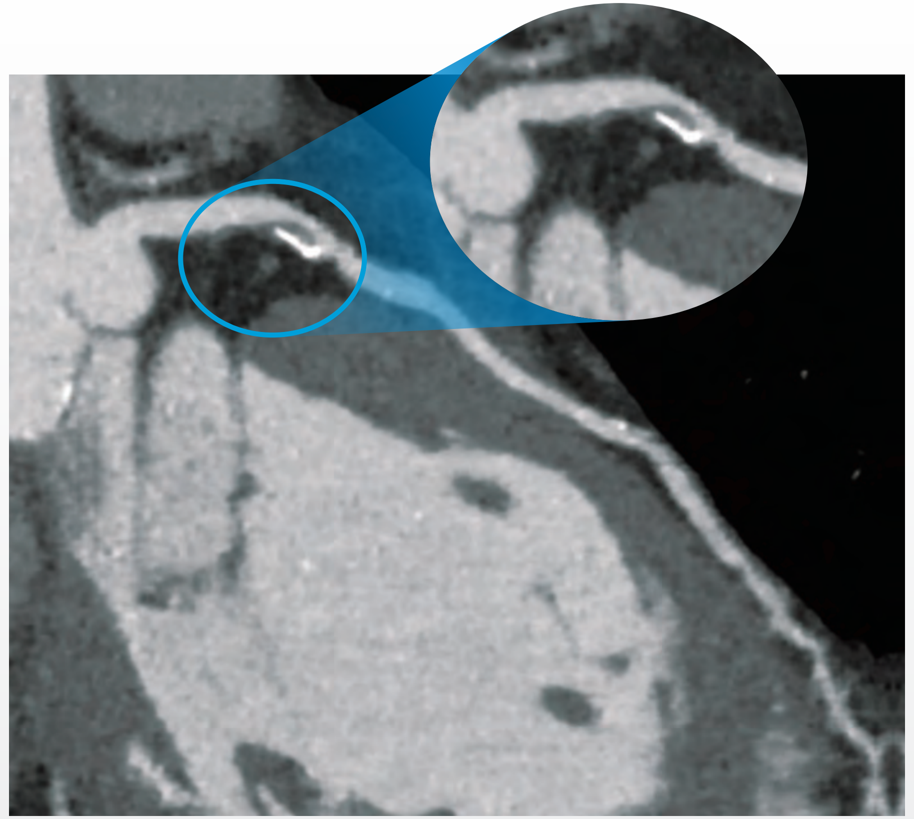


Object size	CTDIvol
3 mm at 0.3%	5.3 mGy
2 mm at 0.3%	10.5 mGy
1.5 mm at 0.3%	22.6 mGy
Scan parameters	
10 mm (with AiCE)	
Phantom	
(CTP344, Phantom Labs)	

The improved LCD helps in better visualization of elements whose HU attenuation values are close to each other. Thus, AiCE provides more clarity in visualizing such structures and could lead to a much more confident diagnosis.

The low contrast detectability performance of AiCE is demonstrated in images below which shows a mixed lesion in the left anterior descending artery. The calcified and non-calcified components can be clearly identified.

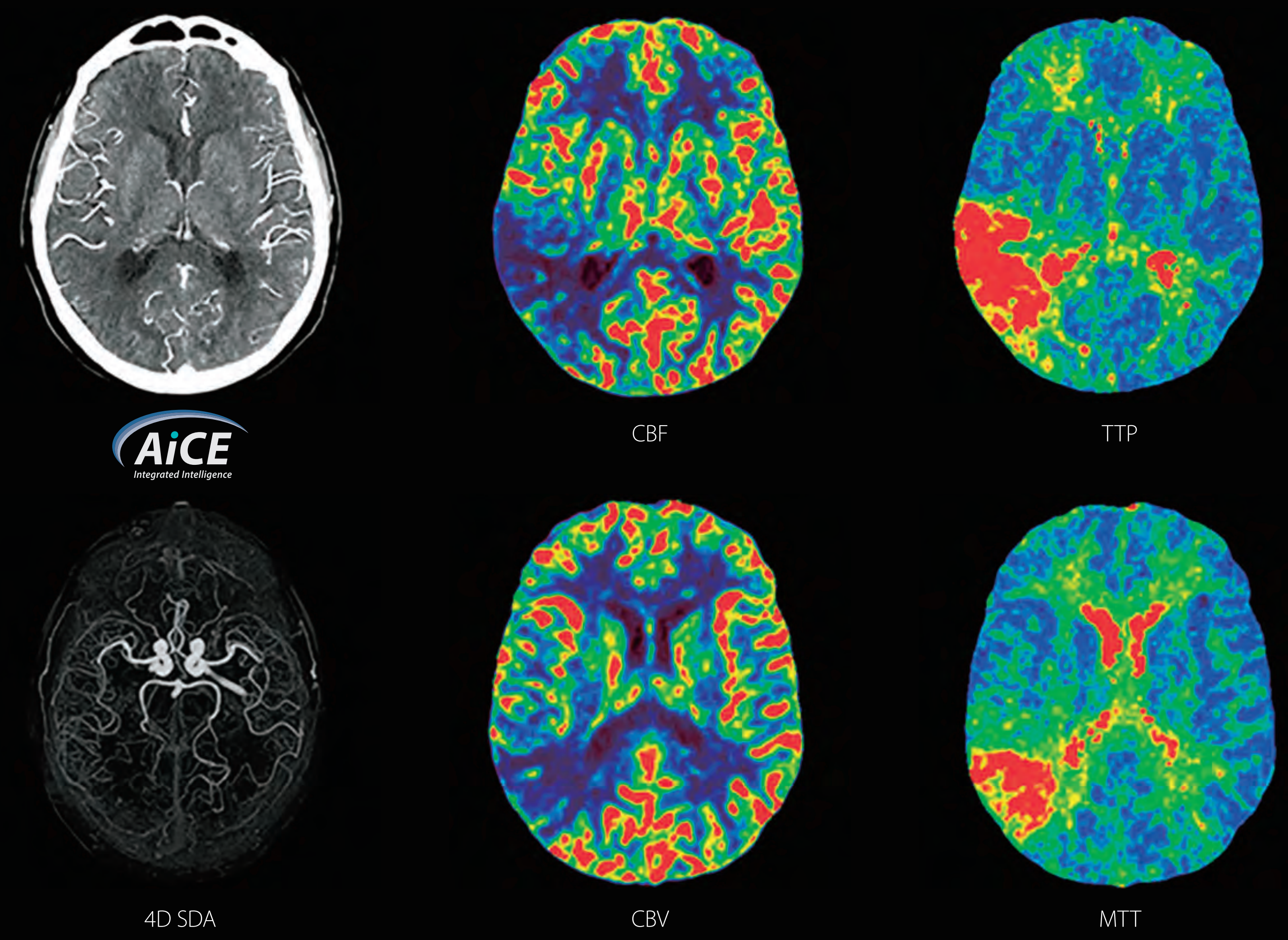




"I really like AiCE because of its low contrast detectability and the much sharper contours."

Ewoud Smit MD, PhD
Radiologist
Radboud University Medical Center, Nijmegen, the Netherlands

Whole brain acute stroke imaging



AiCE applied to low dose 4D whole brain perfusion exams shows remarkable noise reduction.

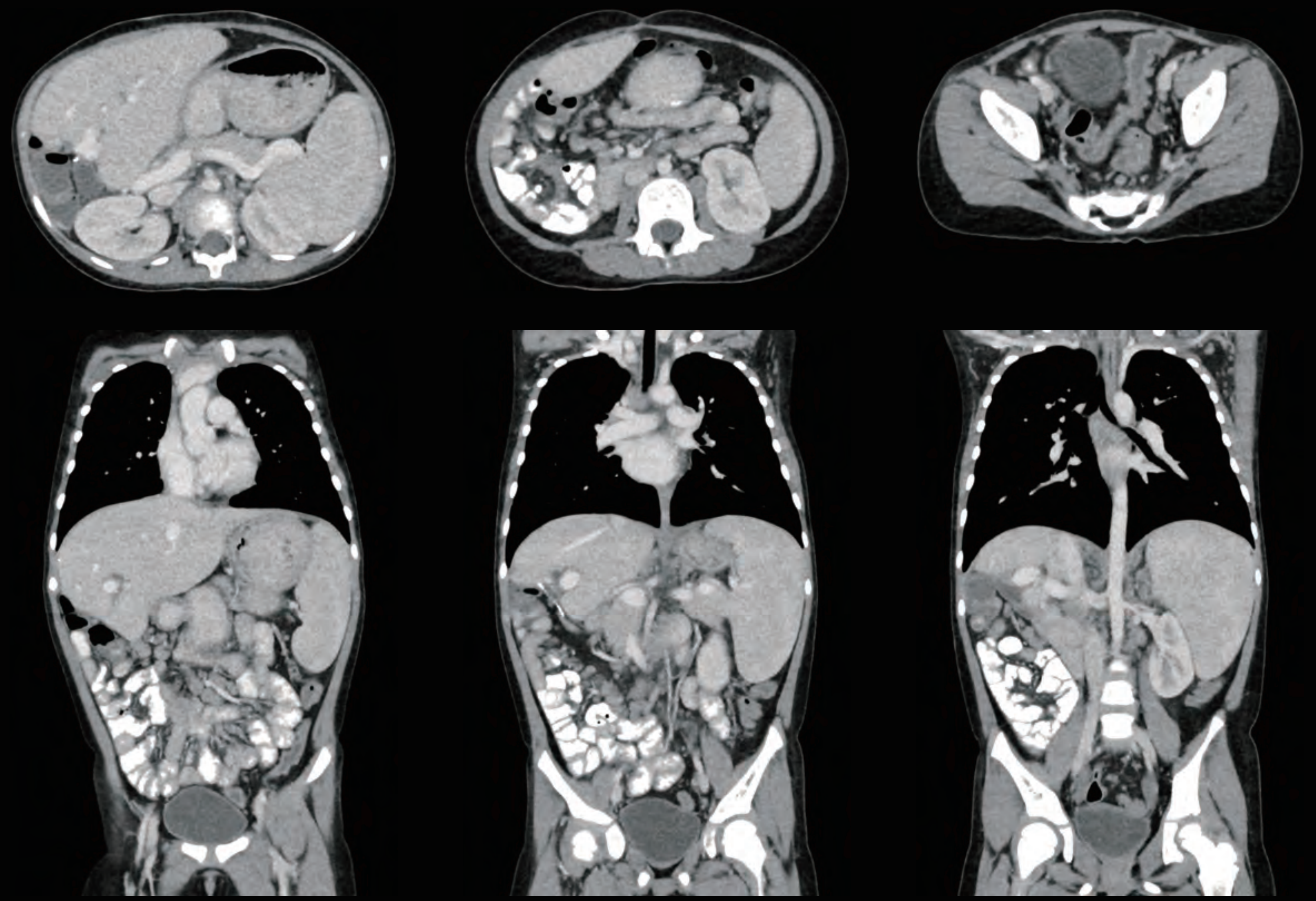
A perfusion deficit is seen in the right posterior parietal lobe corresponding with the right M3 branch occlusion.

The low blood volume is indicative of an infarct which occupies most of the deficit.

Dynamic Volume,
DLP 49.9 mGy·cm, 2.07 mGy·cm (k = 0.0021)

Aquilion ONE
PRISM Edition

Pediatric low dose body exam



7-year-old girl requiring a post contrast enhanced chest and abdominal CT examination was imaged with an average CTDI of 1.1 mGy and total DLP of 49.9 mGy·cm.

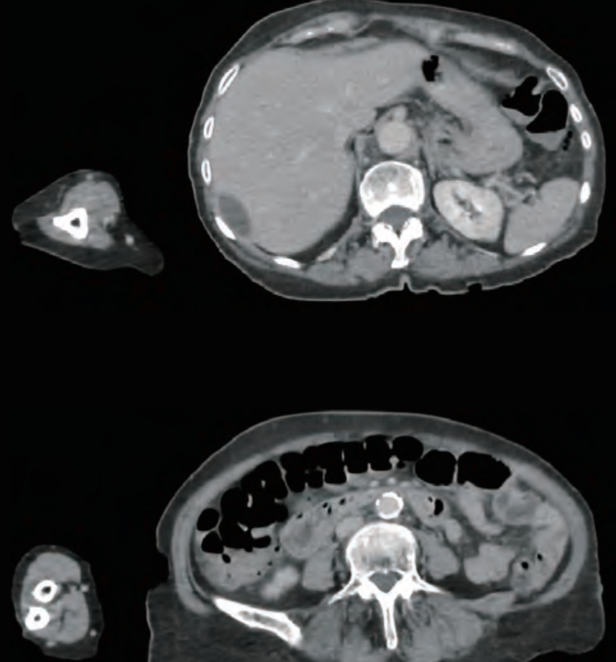
AiCE has been trained to be robust across all body regions, and all patient sizes.

With up to 82% dose reduction automatically applied as part of the scan protocol, (compared to FBP), AiCE affords an additional layer of protection for the youngest patients.

CTDI 1.1 mGy, DLP 49.9 mGy·cm

Aquilion ONE
GENESIS Edition

Whole body trauma scan



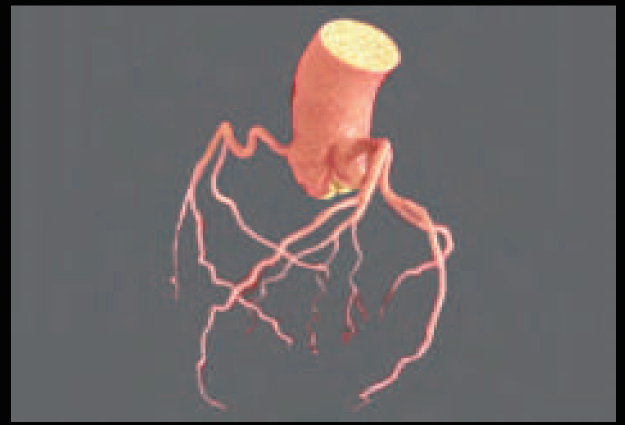
Excellent image quality is obtained with AiCE, even when a patient needs to be scanned with arms by the side.

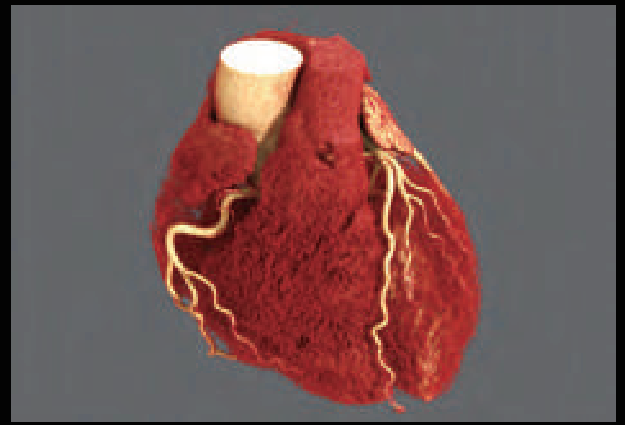
The Aquilion CT series has taken a holistic approach optimizing each component of the imaging chain to maximize the low dose ability of AiCE.

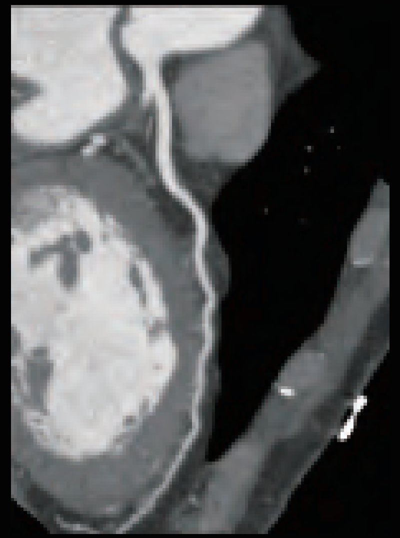
CTDI 7.5 mGy, DLP, 341 mGy·cm
Effective Dose: 5.1 mSv (k = 0.014)

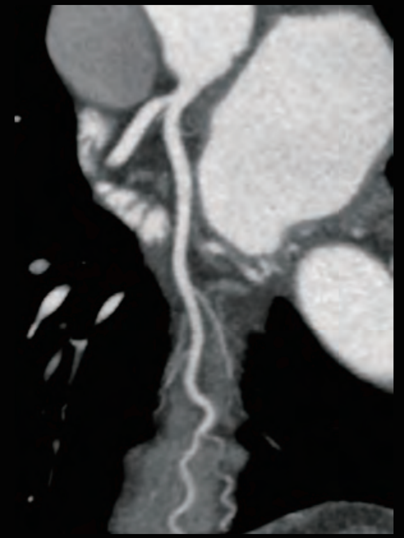
Aquilion Prime SP

Prospective ECG helical cardiac CTA









A SURECardio prospective scan was performed with an AiCE protocol with a low 2.5 mSv total dose and excellent image quality.

Global illumination rendering in combination with the sharp low noise AiCE data provides life-like 3D representations of patient anatomy.

SURECardio Ultra Helical,
CTDI 10.2 mGy, DLP, 179 mGy·cm
Effective Dose: 2.5 mSv (k = 0.014)

Aquilion Lightning

80 detector row Ultra Helical CT

Ultra-High Resolution humeral chondroma

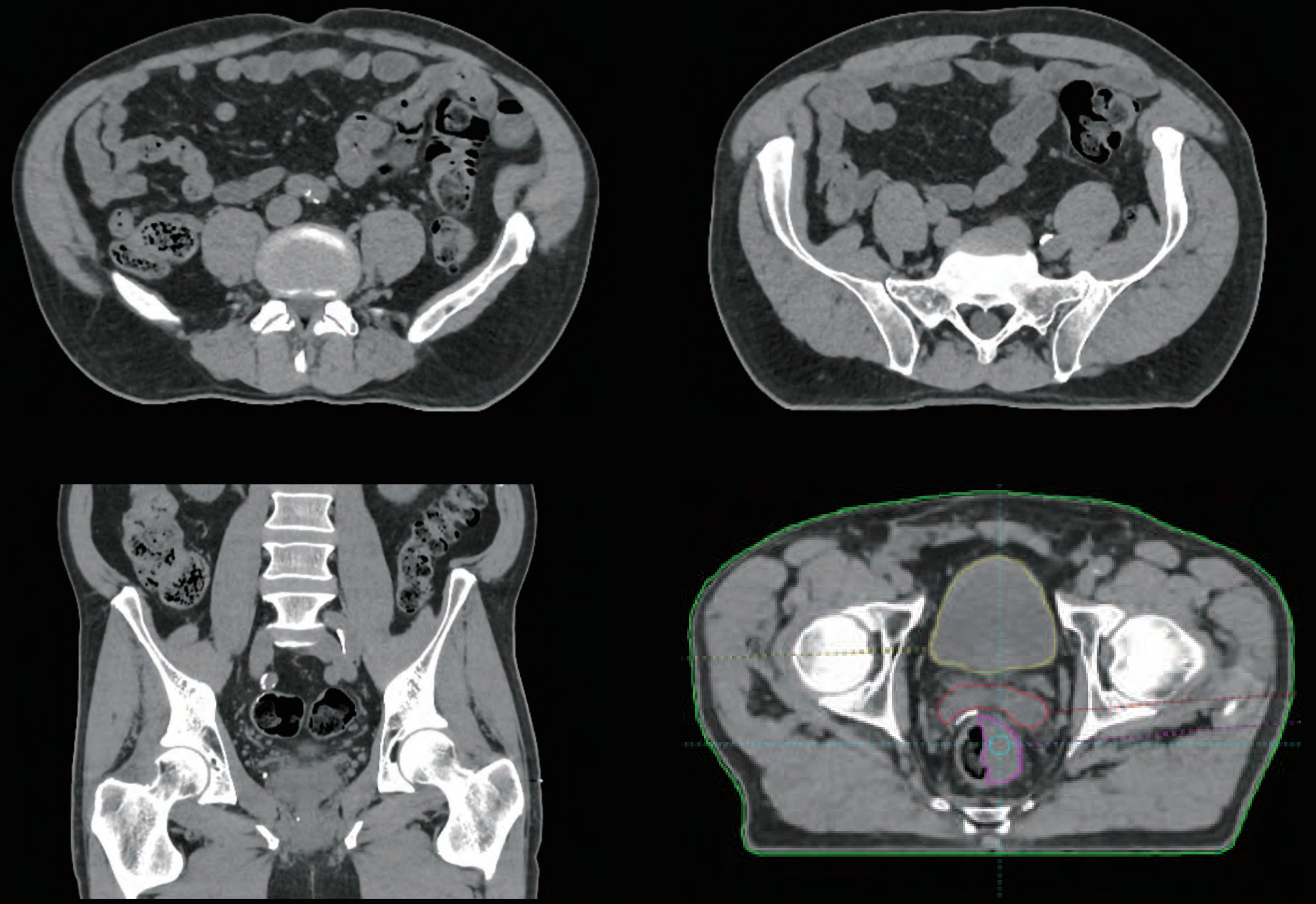
A 0.25 mm helical scan reconstructed with 1024 matrix and AiCE is shown here with Global illumination rendering. It demonstrates a chondroma in the left humeral head in outstanding detail.

Aquilion Precision is the worlds first Ultra-High Resolution CT commercially available. The result of 10 years collaborative innovation including AiCE broke through the long standing noise barrier to bring you CT exams at twice the resolution with dose levels equivalent to standard CT dose levels.

CTDIvol : 20.7 mGy ; DLP : 343.2 mGy·cm
Effective Dose: 4.80 mSv (k = 0.014)

Aquilion Precision

Therapy simulation CT – rectal carcinoma



Highly targeted radiation therapy requires accurate planning, demanding CT simulation scans to be high resolution, low noise, and with accurate CT numbers.

The incredibly clear resolution shown in this planning CT is provided by AiCE reconstruction.

The improved low contrast detectability allowed clear delineation of the rectal tumor facilitating accurate contouring for therapy simulation planning.

CTDI 10.1 mGy, DLP 369.9 mGy·cm,
5.54mSv (k = 0.015)

Aquilion Exceed LB

AiCE publications for CT

Deep learning reconstruction versus iterative reconstruction for cardiac CT angiography in a stroke imaging protocol: reduced radiation dose and improved image quality.
Bernard A, Comby PO, Lemogne B, Haioun K, Ricolfi F, Chevallier O, Loffroy R.
Quant Imaging Med Surg. 2021 Jan;11(1):392-401. doi: 10.21037/qims-20-626.

Conclusions: The use of a DLR algorithm for cardiac CTA in an acute stroke imaging protocol reduced the radiation dose by about 40% and improved the image quality by about 50% compared to an iterative reconstruction algorithm.

Deep Learning Versus Iterative Reconstruction for CT Pulmonary Angiography in the Emergency Setting: Improved Image Quality and Reduced Radiation Dose
Marc Lenfant, Olivier Chevallier, Pierre-Olivier Comby, Gregory Secco, Karim Haioun, Frederic Ricolfi, Brivael Lemogne and Romaric Loffroy
Diagnostics 2020, 10, 558; doi:10.3390/diagnostics10080558

Conclusions: DLR both significantly improved the image quality and reduced the radiation dose of CTPA examinations as compared to the hybrid-IR technique.

Possibility of Deep Learning in Medical Imaging Focusing Improvement of Computed Tomography Image Quality
Nakamura, Yuko; Higaki, Toru; Tatsugami, Fuminari; Honda, Yukiko; Narita, Keigo; Akagi, Motonori; Awai, Kazuo
J Comput Assist Tomogr. 2020 Mar/Apr;44(2):161-167

Conclusions: Because of the high performance of DL with respect to image recognition, its applicability for radiological imaging is increasing and radiologists must become familiar with DL. As this method improves the image quality, it is of diagnostic importance. Especially focused on CT image reconstruction, unlike MBIR, DLR can improve the quality of CT images of various areas even at low-dose radiation settings. Therefore, DLR may represent a breakthrough in image reconstruction field.

Improvement of image quality at CT and MRI using deep learning
Higaki, Toru; Nakamura, Yuko; Tatsugami, Fuminari; Nakaura, Takeshi; Awai, Kazuo
Japanese Journal of Radiology (2019) 37:73–80

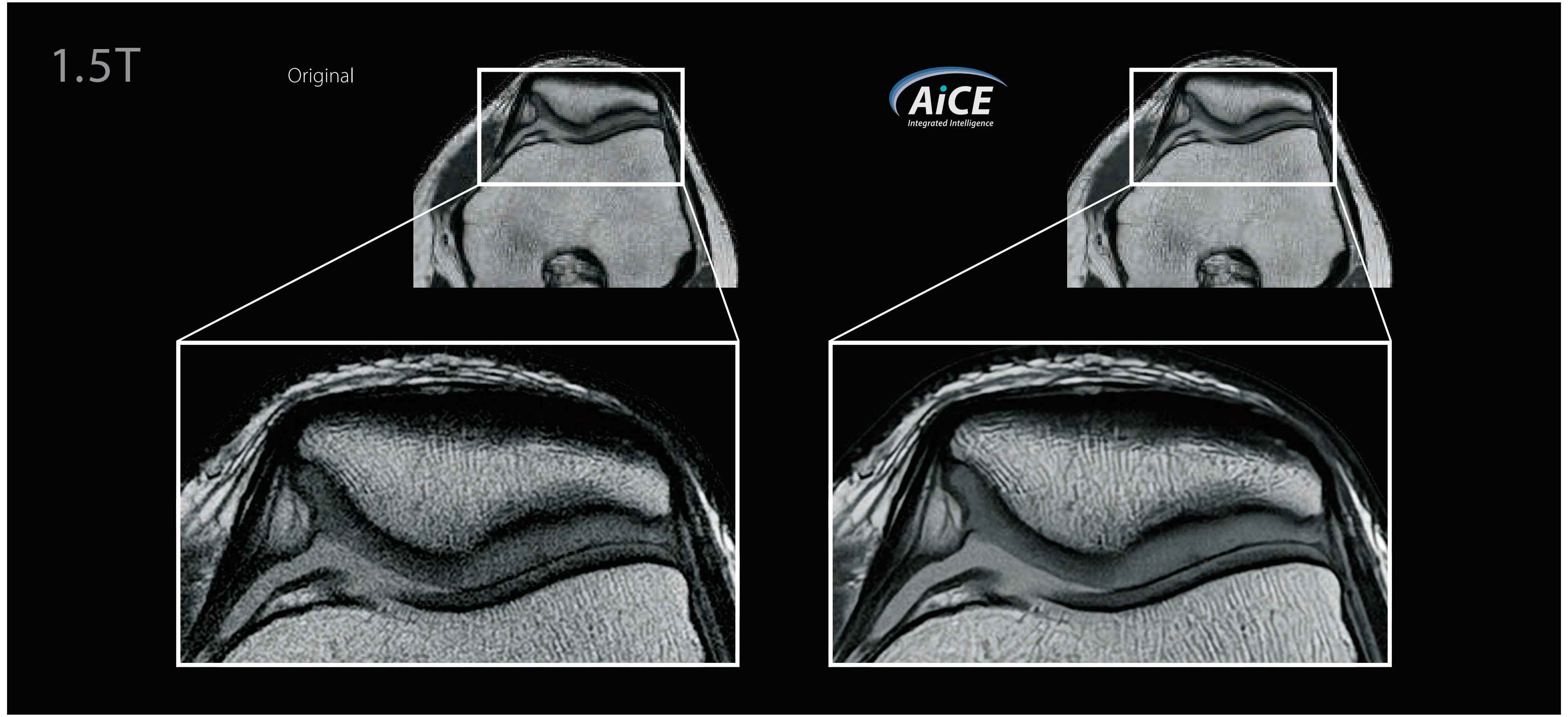
Abstract: Deep learning has been developed by computer scientists. Here, we discuss techniques for improving the image quality of diagnostic computed tomography and magnetic resonance imaging with the aid of deep learning. We categorize the techniques for improving the image quality as "noise and artifact reduction", "super resolution" and "image acquisition and reconstruction". For each category, we present and outline the features of some studies.

Intelligent healthcare made easy

Introducing Altivity, our bold new approach to AI innovation that uses smart technologies to make a whole new level of quality, insight and value across the entire care pathway, possible.

A new era of clarity has begun in MR

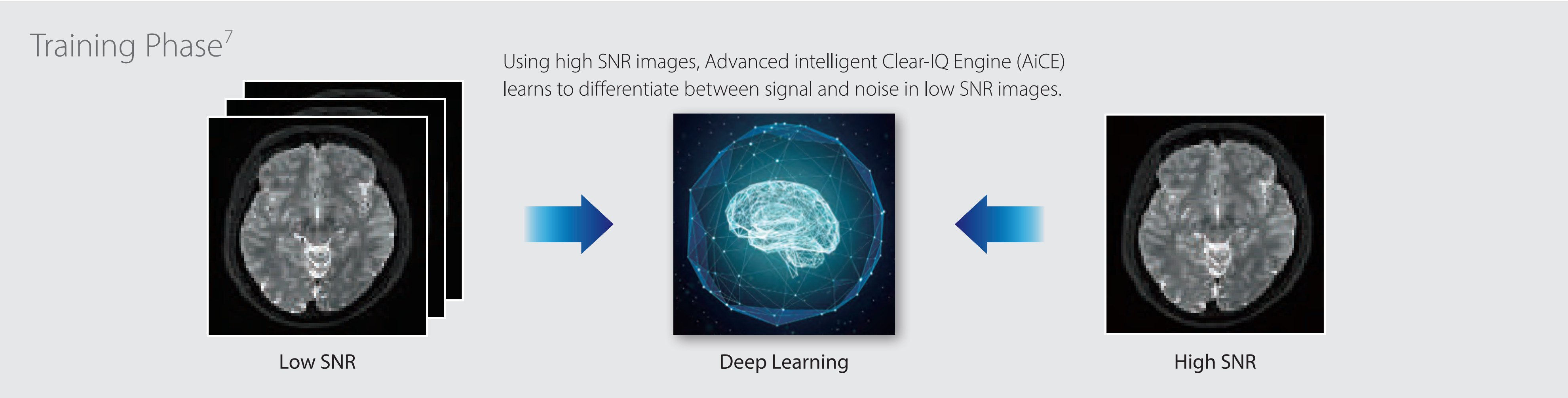
Advanced intelligent Clear-IQ Engine (AiCE) is the world's first fully integrated MR Deep Learning Rreconstruction technology producing stunning MR images that are exceptionally detailed and with the low-noise properties you might expect of a high SNR image. With AiCE now expanding across a broad range of anatomies, contrast and applications, you no longer need to compromise between resolution and speed.

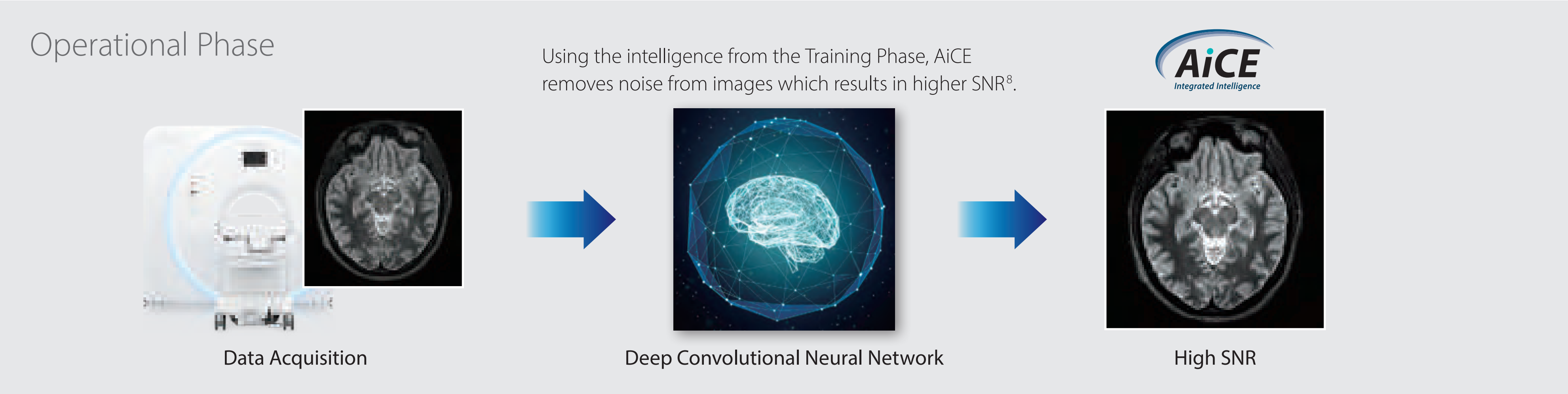


PDw 0.15 × 0.15 × 2 mm
4:52

See through the noise. This is intelligence

Producing stunning MR images that are exceptionally detailed. Harnessing the enormous computational power of a Deep Convolutional Neural Network (DCNN), AiCE is trained to restore low SNR MR data to match the properties of higher SNR images.



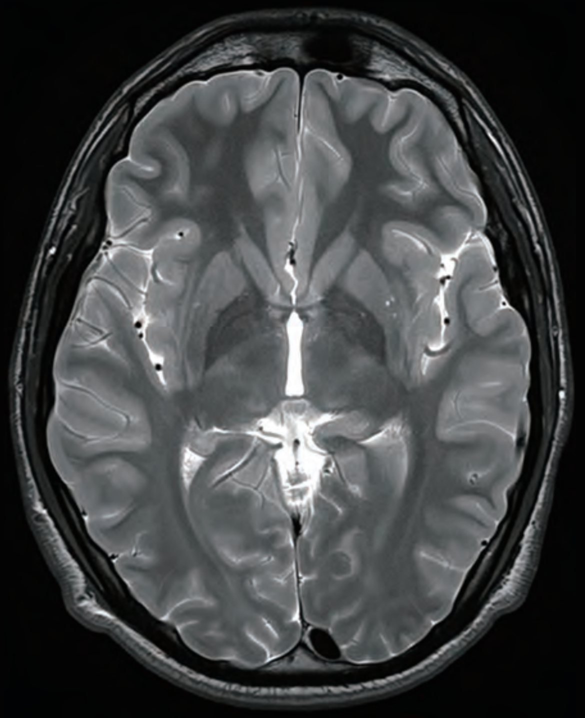


7 The AI training is performed only during the development stage. The product which is manufactured and shipped has no ability or functionality to re-train on-site
8 Higher SNR compared to a reconstruction filter of NL2

Sharp, clear, and distinct images. See through the noise

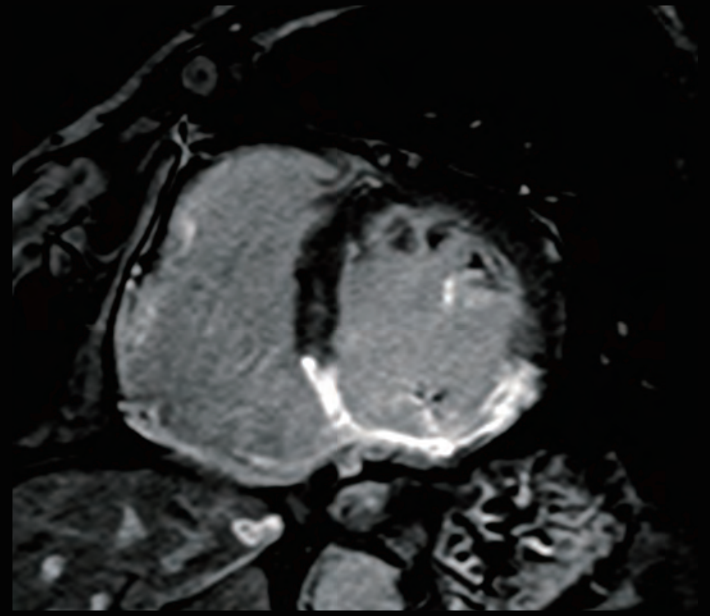
AiCE intelligently removes noise from images which results in higher SNR[9] and enables increased resolution. By improving SNR you can achieve sharp, clear, and distinct images utilizing the power of Deep Learning to see through the noise.

Brain



T2w

Cardiac



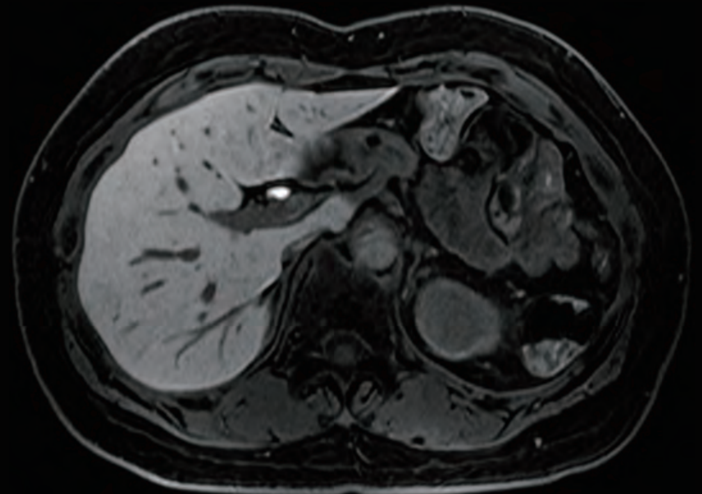
T1w

Courtesy of Kyorin University Hospital, Japan

L-Spine

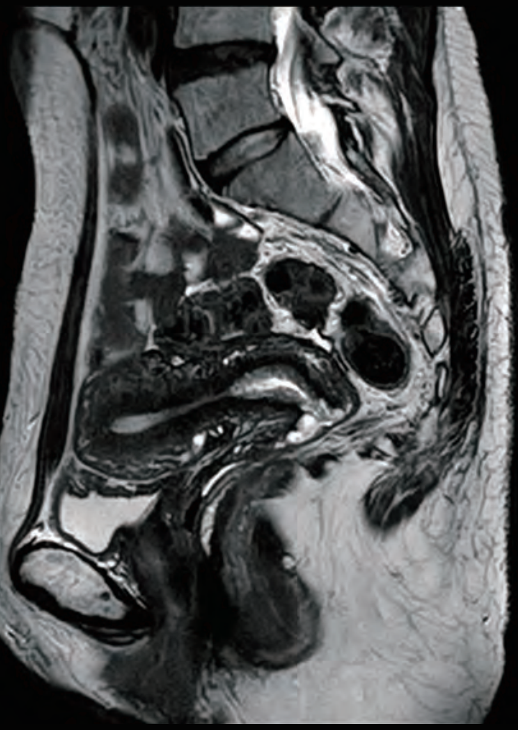
T2w

Liver



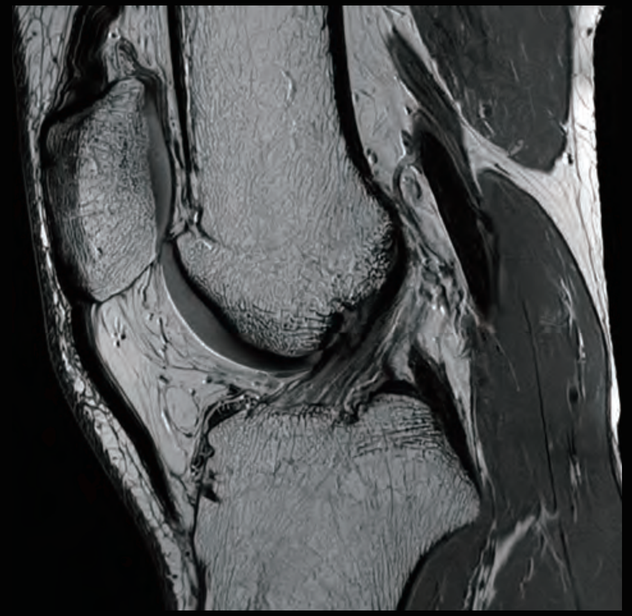
T1w

Pelvis



T2w

Knee



PDw

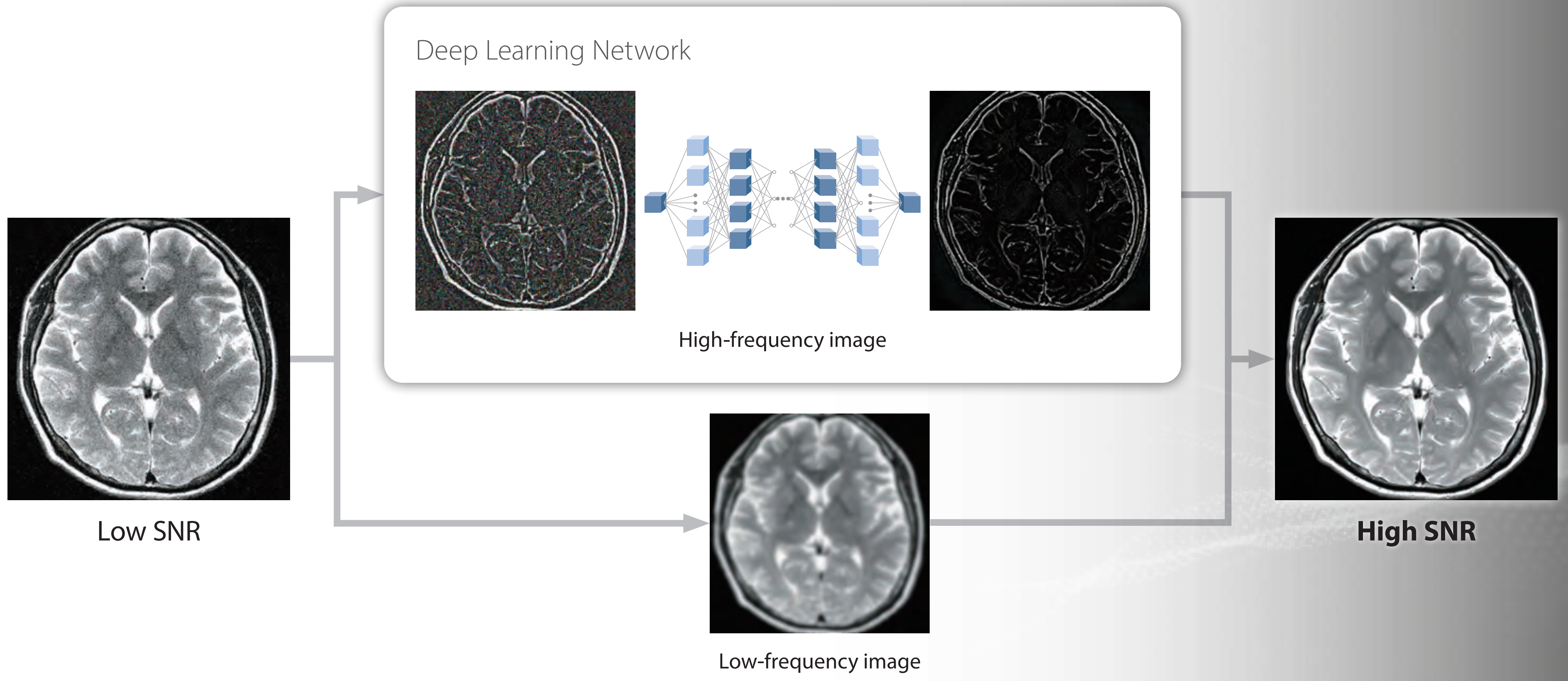
Courtesy of Fujita Health University Hospital, Japan

9 AiCE provides higher SNR compared to typical low pass filters

AiCE in MR image reconstruction

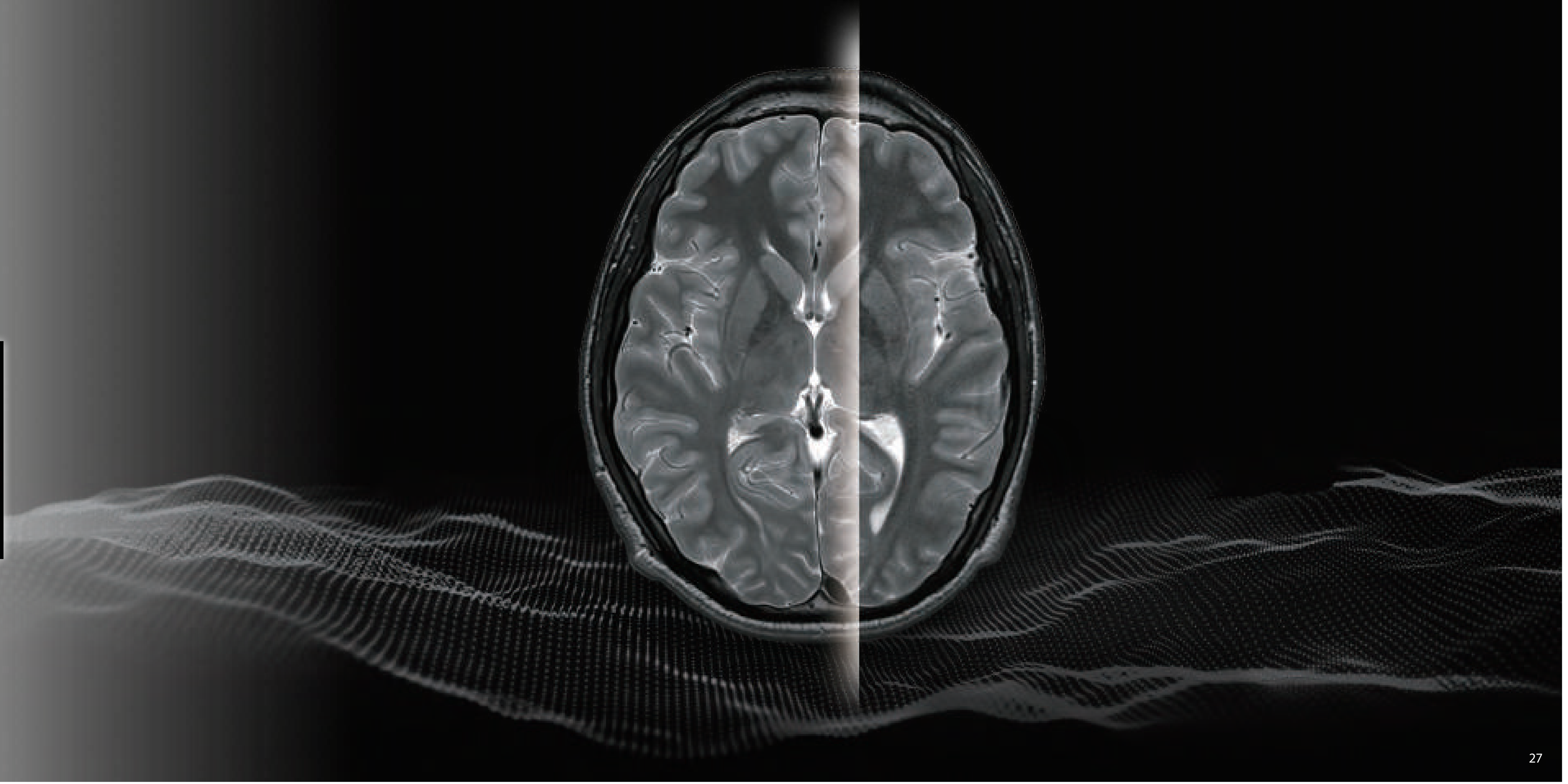
AiCE has been carefully designed by scientists with expert knowledge of MR physics and signal processing together with specialists in programming advanced AI neural networks to ensure accurate and robust results for all patient studies. To overcome contrast and signal variation in MRI data, AiCE denoising is restricted to high-frequency noise leaving low frequency information untouched.

The amount of noise reduction and image sharpness can be fine tuned to cater for your site preferences to ensure optimal diagnostic image quality is provided for all patients.



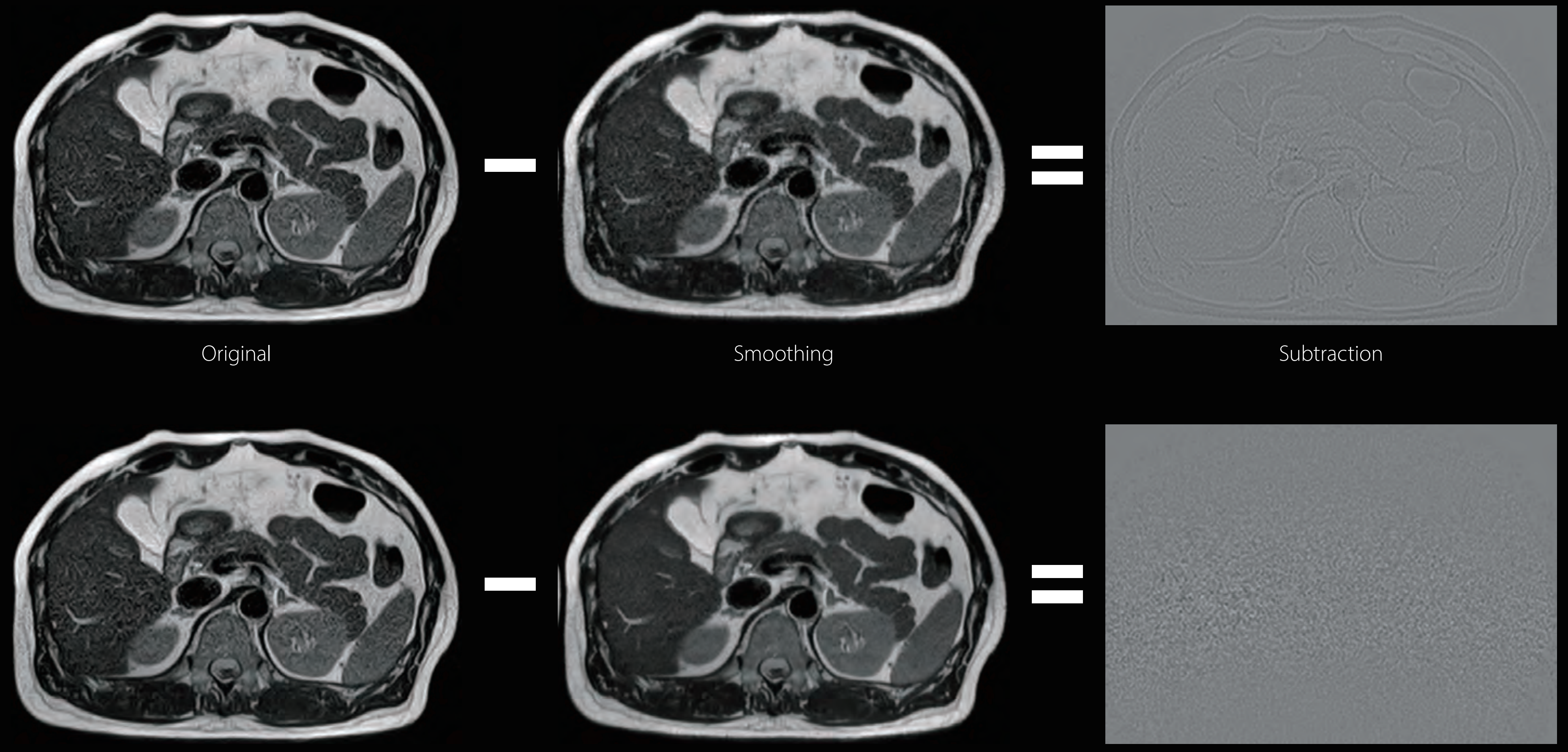
At the completion of training the AiCE network undergoes an important validation step where the network is tasked to restore low quality data without seeing the target images. These high quality images are used by the AI scientist to evaluate the networks performance under simulated clinical conditions.

As a novel approach to MRI reconstruction, AiCE was also independently tested by model observer and human observer studies that validate the efficacy and safety of this powerful reconstruction process for routine clinical practice.



Intelligently removes noise

The following images demonstrate noise subtraction from the same original image utilizing a conventional filter compared to AiCE. With the conventional filter some necessary anatomical information has been removed along with the noise. AiCE intelligently identifies noise from the original image due to the Deep Learning algorithms.

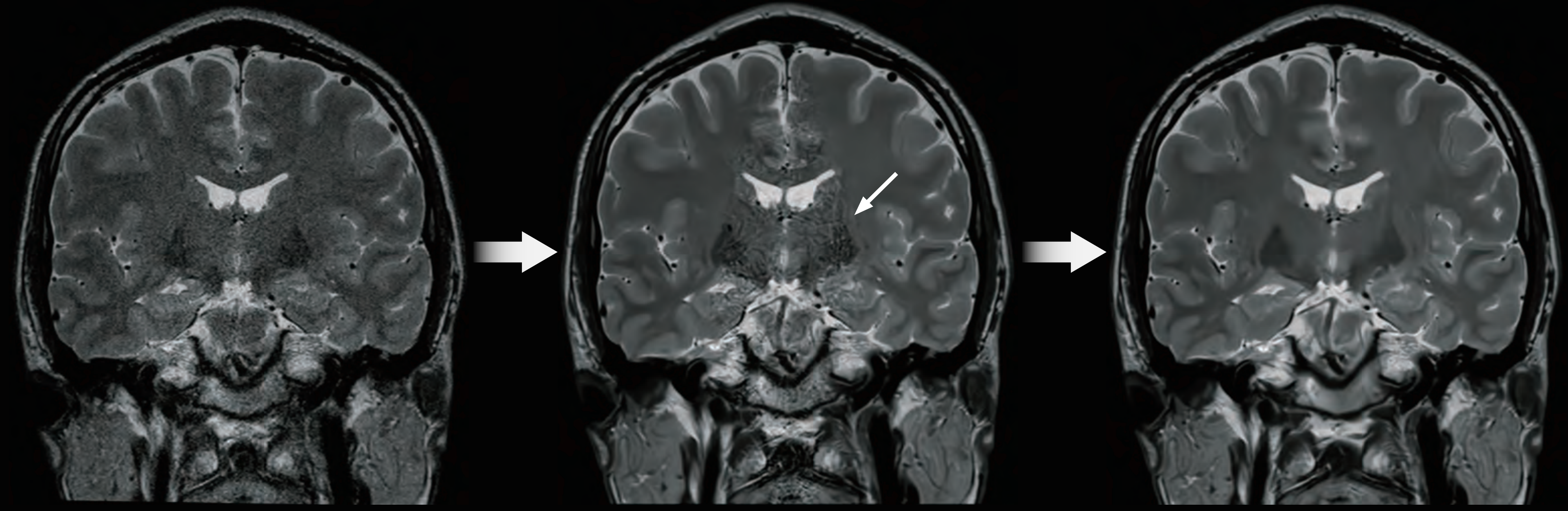


Original — Smoothing = Subtraction

Original — AiCE = Subtraction

AiCE enhances parallel imaging robustness

In the most recent version of AiCE (Version 7) noise estimation has been enhanced to allow noise to be removed from the section where g-factor was considered (arrow).

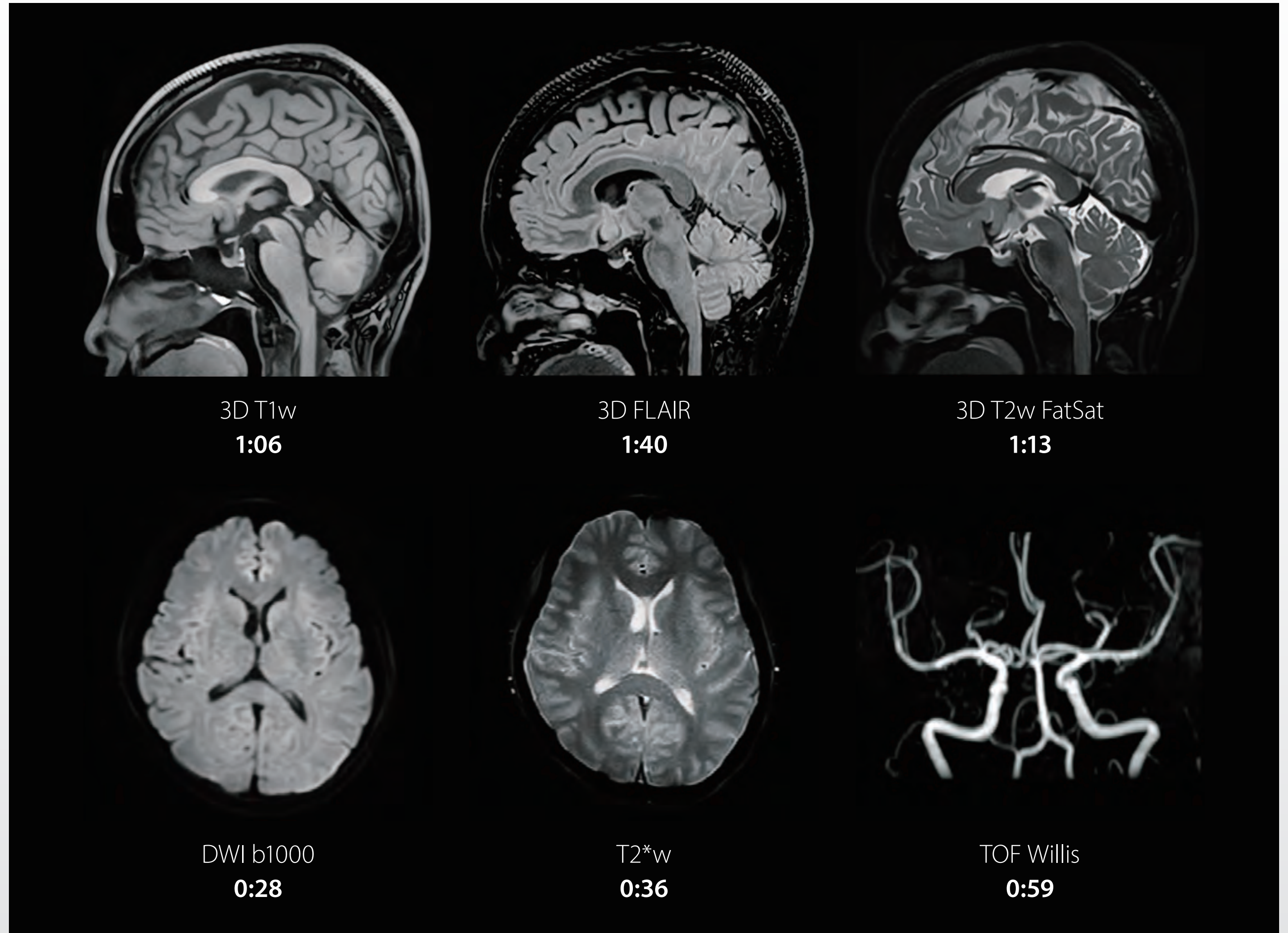


Original → → AiCE

Forging a path from research to clinical practice

3D *Welcome Pack*

A standardized 3D brain MR examination in 6 minutes[10]



Courtesy of University of Bordeaux, Institute of Bio-Imaging, France

"With DLR we can achieve both high resolution images without losing time or signal and reduce the image acquisition time."

"The first application, and this is revolutionary in medical imaging history, is that we no longer have to improve the signal or the spatial resolution because the DLR will allow us to correct afterwards what couldn't be corrected at the beginning."

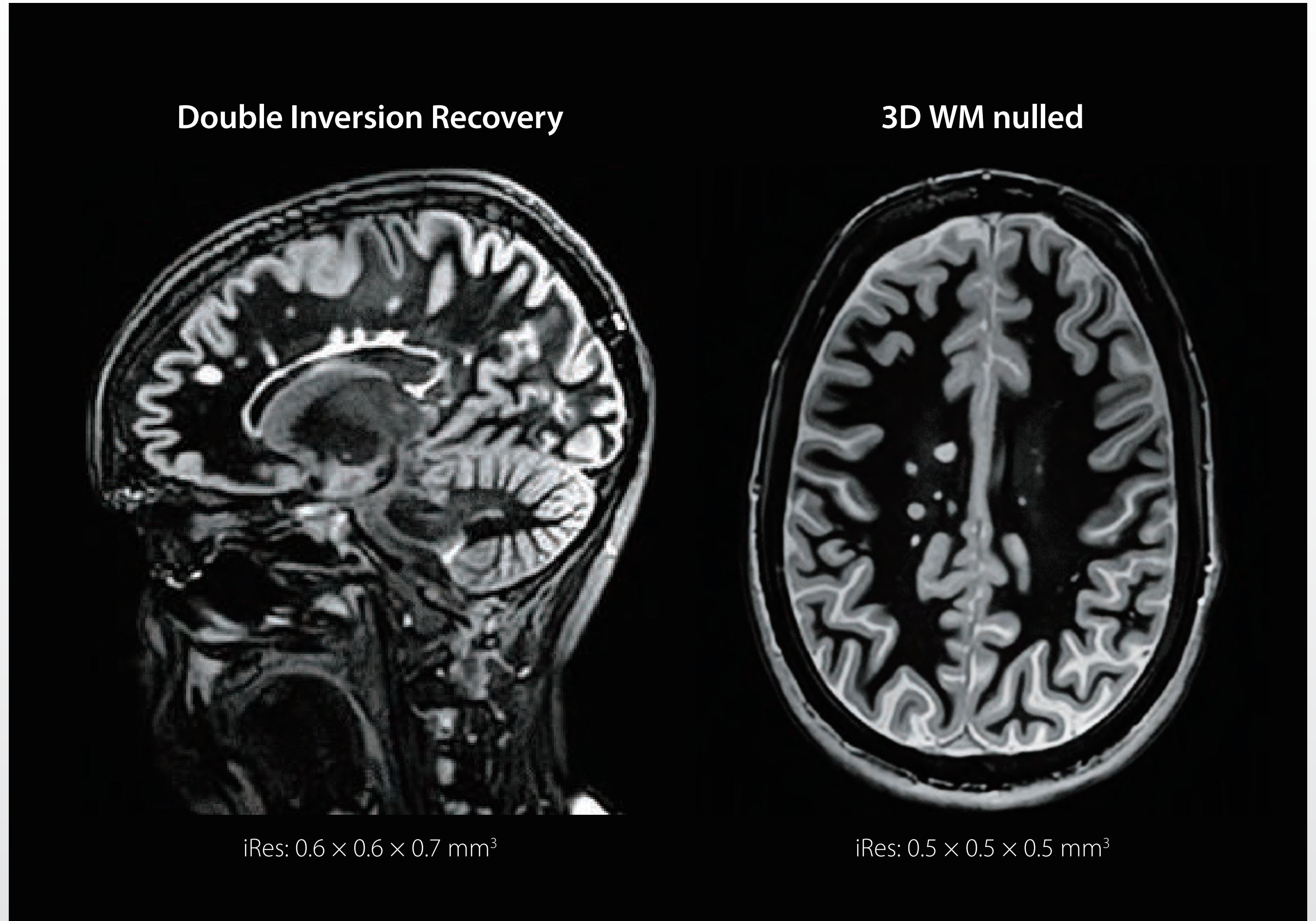
Vincent Dousset, MD, PhD (PU-PH)
Director of IBIO
University of Bordeaux and University Hospital of Bordeaux

"We fine tuned the DLR on our 3T system in order get similar images that we could have on a very high field 7T system."

Thomas Tourdias, MD, PhD (PU-PH)
University of Bordeaux and
University Hospital of Bordeaux

Multiple sclerosis

Advanced methods to compare early and progressive stages and to evaluate the efficiency of treatment

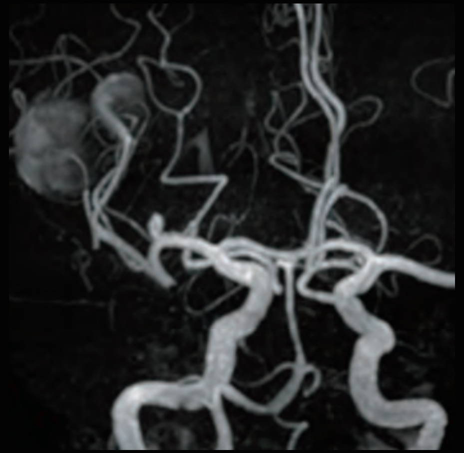


Courtesy of University of Bordeaux, Institute of Bio-Imaging, France

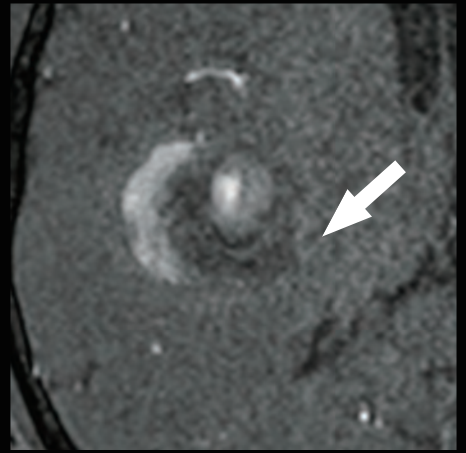
10 Actual scan time reductions may vary by case

High resolution image for visualization of small lesion

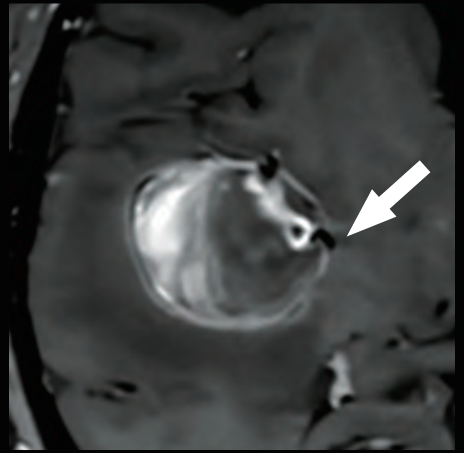
3T



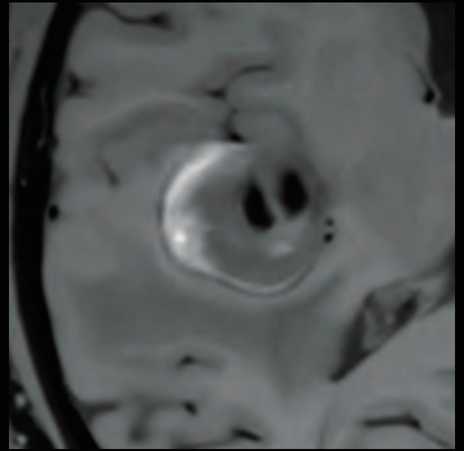
MRA



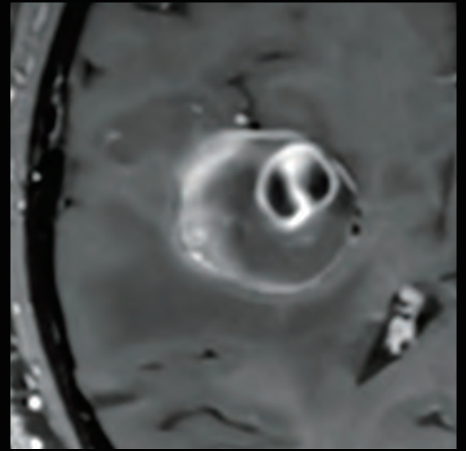
MRA – Original image



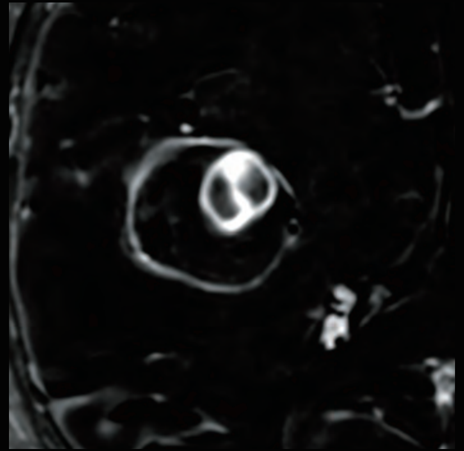
CE MPV3D



MPV3D



CE MPV3D



Subtraction

AiCE provides high resolution MRI scans in clinically acceptable time.

To visualize small anatomical detail traditionally required long scan times to ensure adequate SNR.

MPV3D: 10 × 10 cm,
0.6 × 0.6 mm resolution, 1.0 mm
MRA: 20 × 20 cm,
0.7 × 0.6 mm resolution, 0.8 mm

Courtesy of Fujita Health University, Japan
Sponsored symposium at 48th JSMRM

Faster scanning for patient in pain

3T

Conventional

T2w 0.8 × 0.8 mm resolution
2:20

AiCE Integrated Intelligence

T2w 0.6 × 0.6 mm resolution
1:48

AiCE provides high resolution MRI scans in clinically acceptable time.

Fast exam times are particularly beneficial when imaging the cervical spine as patients often have neck pain making it difficult to remain motionless for long periods of time.

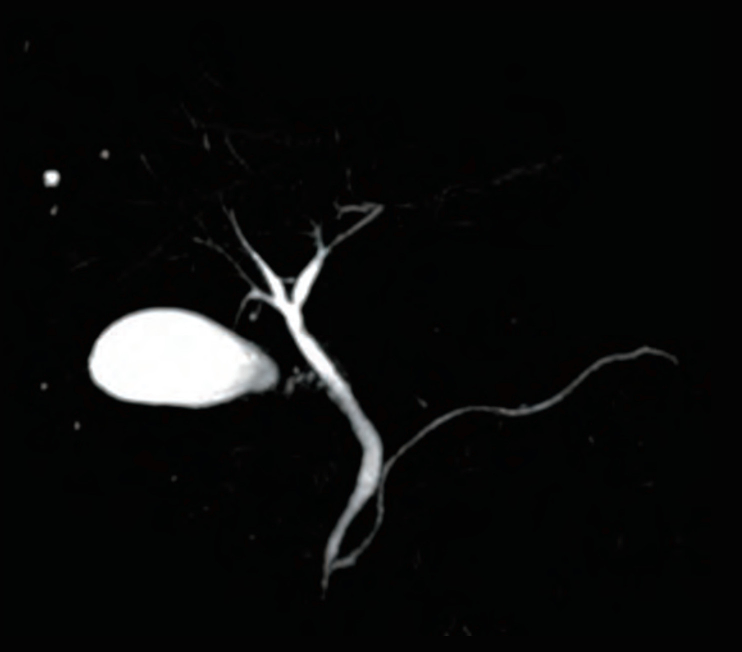
AiCE may help you to reduce repeat scans due to motion artifacts thereby reducing overall exam time for better patient cooperation.

Courtesy of Kikuna Memorial Hospital, Japan

Speed and clarity in combination with Fast 3D

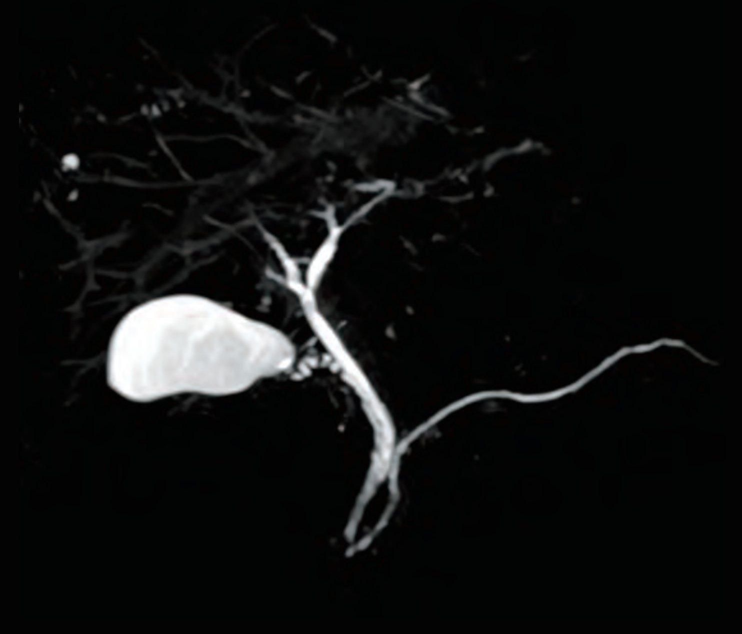
1.5 T

Conventional



2:34

Fast 3D + AiCE



0:20

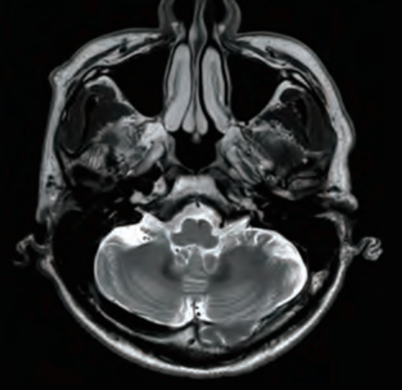
AiCE reconstruction has been designed to work for a wide range of pulse sequences and forms a powerful combination together with Fast 3D.

This MR Cholangiopancreatography was acquired in just 20 seconds which is short enough to have the patient hold their breath. Together, AiCE and Fast 3D enable you to set new standards in abdominal MR imaging to provide sharp, clear and distinct anatomical detail free from motion blur.

Higher acceleration for reducing susceptibility

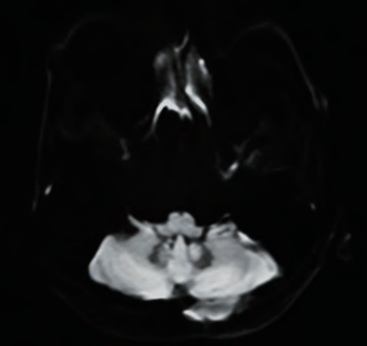
3T

AiCE

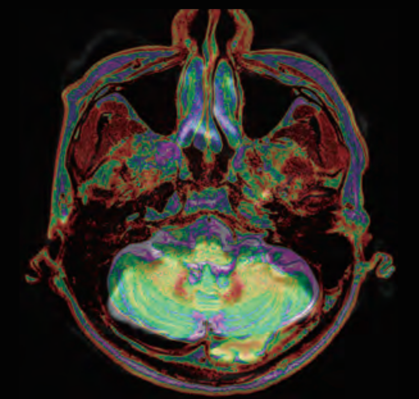


T2WI

SPEEDER

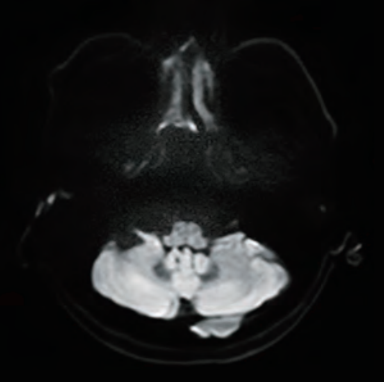


SPEEDER × 2

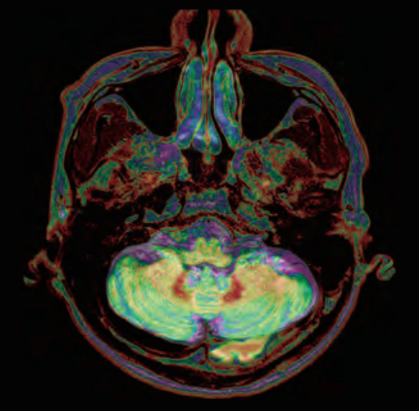


Fusion

Exsper + AiCE



Exsper × 6



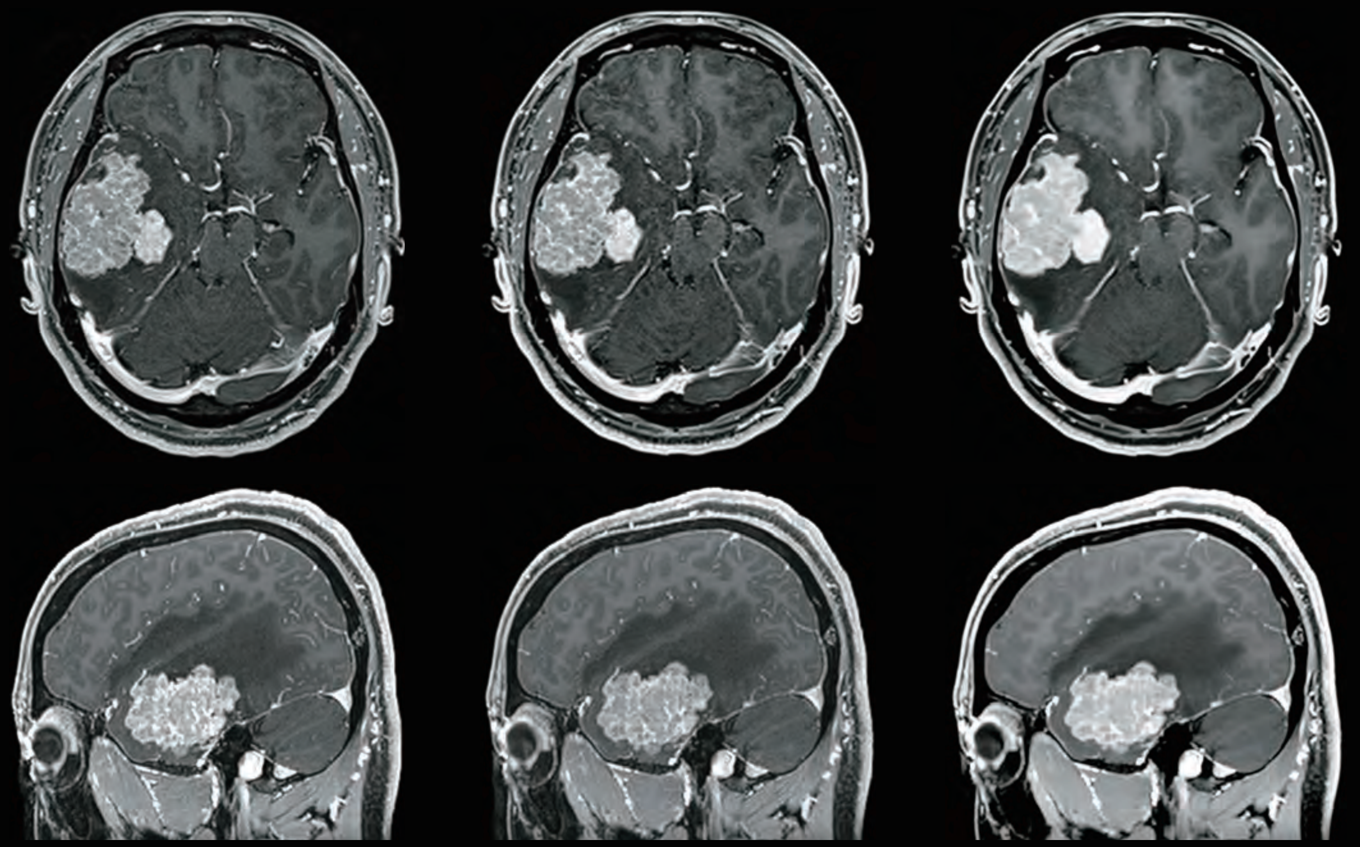
Fusion

It is technically very difficult to increase the acceleration factor of parallel imaging due to artifacts based on g-factor. However, the combination of AiCE with improved noise estimation and Canon's Exsper, which is a k-space based parallel imaging method, allow you to prioritize fast scans while reducing distortion artifacts.

AiCE in combination with Compressed SPEEDER

1.5 T

Compressed SPEEDER | Compressed SPEEDER + AiCE Integrated Intelligence



3D FFE
with SPEEDER × 2.0
6:53

3D FFE
with CS × 4.0
3:27

3D FFE
with CS × 4.0
3:27

AiCE may be used in combination with Compressed SPEEDER.
Normally, 3D sequences require a long scan time, and if you shorten scan time, it is difficult to achieve sufficient signal and/or aliasing artifacts can occur based on g-factor.

In this combination, you can utilize Compressed SPEEDER to scan fast and AiCE to restore SNR by removing noise during image reconstruction.

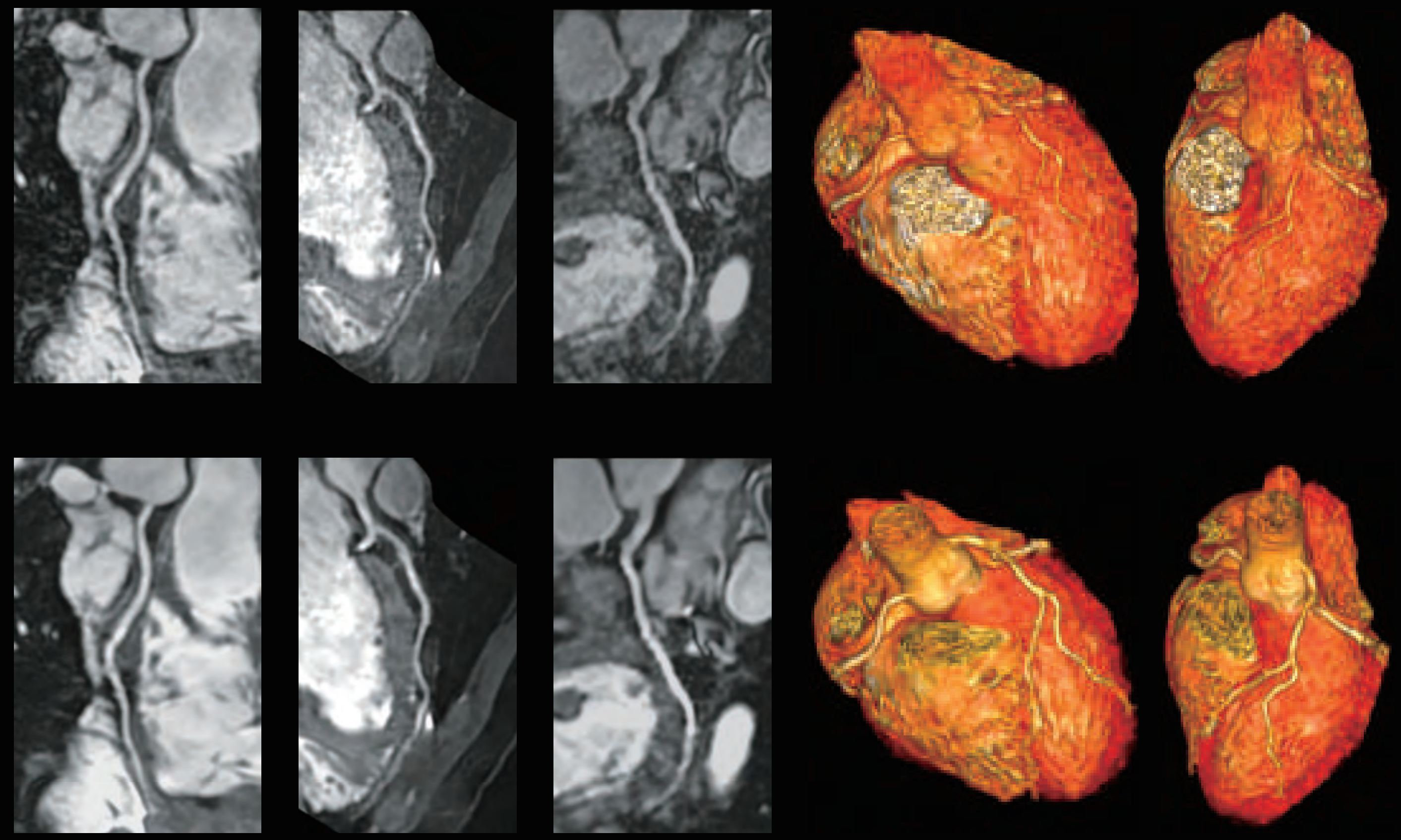
Courtesy of Fujita Health University Hospital, Japan

Utilizing AiCE for volume rendering

1.5 T

Original

AiCE Integrated Intelligence



RCA | LAD | LCX | Volume Rendering

In the reformatted images on the left, you can enhance the visibility of the entire coronary artery utilizing AiCE.

For the volume rendered images on the right, the contrast between the coronary artery and the myocardium is distinctly shown when comparing the original images to images reconstructed with AiCE.
AiCE can remove noise without affecting contrast as demonstrated in these detailed volume rendered images reconstructed with AiCE.

AiCE publications for MR

Deep Learning-based Noise Reduction for Fast Volume Diffusion Tensor Imaging: Assessing the Noise Reduction Effect and Reliability of Diffusion Metrics.
Sagawa, H., Fushimi, Y., Nakajima, S., Fujimoto, K., Miyake, K. K., Numamoto, H., Koizumi, K., Nambu, M., Kataoka, H., Nakamoto, Y., & Saga, T.
Magnetic Resonance in Medical Sciences (2020). 771, 1–7. doi: 10.2463/mrms.tn.2020-0061

Conclusions: Image noise was significantly decreased with dDLR. Although fractional anisotropy (FA) of deep gray matter was overestimated when the number of image acquisitions was one (NAQ1), FA in NAQ1 with dDLR became closer to that in NAQ5.

Deep Learning Based Noise Reduction for Brain MR Imaging: Tests on Phantoms and Healthy Volunteers.
Kidoh, M., Shinoda, K., Kitajima, M., Isogawa, K., Nambu, M., Uetani, H., Morita, K., Nakaura, T., Tateishi, M., Yamashita, Y., & Yamashita, Y.
Magnetic Resonance in Medical Sciences (2019). doi: 10.2463/mrms.mp.2019-0018

Conclusions: dDLR reduces image noise while preserving image quality on brain MR images.

Effects of Deep Learning Reconstruction Technique in High-Resolution Non-contrast Magnetic Resonance Coronary Angiography at a 3-Tesla Machine.
Yokota, Y., Takeda, C., Kidoh, M., Oda, S., Aoki, R., Ito, K., Morita, K., Haraoka, K., Yamashita, Y., Iizuka, H., Kato, S., Tsujita, K., Ikeda, O., Yamashita, Y., & Utsunomiya, D.
Canadian Association of Radiologists Journal (2020), doi: 10.1177/0846537119900469

Conclusions: Deep learning reconstruction significantly improved the CNR of coronary arteries on HR-MRCA, resulting in both higher visual image quality and better vessel traceability compared with C-MRCA.

Ultrashort echo time time-spatial labeling inversion pulse magnetic resonance angiography with denoising deep learning reconstruction for the assessment of abdominal visceral arteries.
Mori, R., Kassai, Y., Masuda, A., Morita, Y., Kimura, T., Nagasaka, T., Nishina, T., Tanaka, S., Miyazaki, M., Takase, K.
Canadian Association of Radiologists Journal (2021), doi: 10.1002/jmri.27481

Conclusions: dDLR improved SNR with reducing artifacts related to radial sampling, while maintaining the contrast.

Compressed sensing and deep learning reconstruction for women's pelvic MRI denoising: Utility for improving image quality and examination time in routine clinical practice.
Ueda, T., Ohno, Y., Yamamoto, K., Iwase, A., Fukuba, T., Hanamatsu, S., Obama, Y., Ikeda, H., Ikedo, M., Yui, M., Murayama, K., & Toyama, H.
European Journal of Radiology (2021), doi: 10.1016/j.ejrad.2020.109430

Conclusions: Image quality and shorten examination time for T2-weighted imaging in women's pelvic MRI can be significantly improved by using Compressed SPEEDER with AiCE in comparison with conventional SPEEDER, although other sequences were not tested.

AiCE
Integrated Intelligence

Efficient workflows

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